FOOD-BORNE PATHOGENS

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Contents

Summary

Although gastrointestinal disturbances resulting from ingestion of contaminated food may be caused by different factors such as nutritional deficiencies, overeating, and ingesting harmful chemicals and toxins, today's experience shows that infection by microorganisms plays the main role in outbreaks of food-borne diseases.

This chapter concentrates on the most ubiquitous pathogenic microorganisms, particularly the well known pathogens *Clostridium botulinum, Staphylococcus aureus, Salmonella enteritidis* and, *Escherichia coli,* but also includes discussion of emerging new pathogens such as *Listeria monocytogenes* and *Campylobacter jejuni* which were identified in recent decades.

After a short description of the microorganisms, their occurrence in nature and the foods most often contaminated are discussed. The main characteristic symptoms of the disease and the problems of prevention and control are included. .Space does not allow discussion of all aspects of this topic, but readers interested in specific questions will find the Bibliography helpful.

1. Introduction

Food-borne infections and intoxications are significant public health problems all over the world. Centralization of processing and preparation of food is growing, increasing the distance and time between initial preparation and consumer, thus increasing the risk of growth of pathogens during this time. The globalization of food trade results in outbreaks that can spread over wide geographic areas as food is transported across borders. A growing number of pathogens and toxins have been implicated in the etiology of food-borne diseases and new vehicles of transmission have been identified due to the increasing application of analytical epidemiological studies during outbreak investigations and risk factor studies.

More than ten years ago the FAO/WHO sponsored International Conference on Nutrition (ICN, Deember 1992) recognized that hundreds of millions of people suffer from communicable diseases caused by contaminated food and drinking water. According to numerous reports of public health authorities, most of these illnesses are caused by pathogenic bacteria. Although the major problems connected with contamination of food with pathogenic bacteria, viruses and parasites are associated with developing countries, this problem is not limited to those countries.

With todays' improvement in standards of personal hygiene, safe water supply, effective vaccination programs, improvement of food processing technologies and food control infrastructure, food-borne diseases have been considerably reduced in industrialized countries. However, some recent studies show that food-associated illnesses are still widespread. For example in the USA at least 1 in 10 people experience such illnesses each year. A recent British newspaper cited 'More than four million people in the UK, approximately one in ten of the population, suffer from food poisoning each year'. An increase of food-borne illnesses caused by bacteria previously unrelated to food-borne diseases has also been observed. So the problem of food-borne pathogens is still an important part of food safety even in developed countries.

The most common types of microorganisms causing food-borne illnesses will be overviewed in this chapter along with problems connected with control and prevention.

2. Botulism

2.1. General

Botulism is a rare but serious paralytic illness caused by a nerve toxin that is produced by the bacterium *Clostridium botulinum*. The word botulism comes from the Latin word *botulus*, meaning sausage. There are three main kinds of botulism. Food-borne botulism is caused by eating foods that contain the botulism toxin. Wound botulism is caused by toxin produced from a wound infected with *Clostridium botulinum*. Infant botulism is caused by consuming the spores of the botulinum bacteria, which then grow in the intestines and release toxin. All forms of botulism can be fatal and are considered medical emergencies. Food-borne botulism can be especially dangerous because many people can be poisoned by eating contaminated food. This microorganism is a rod-shaped soil bacterium. It is saprophytic, spore-forming, gas-forming and anaerobic. Different types of these toxin-producing bacteria are distinguished on the basis of the serological specifity of their toxins. According to ***Bergey's Manual of Systematic Bacteriology***, there are seven types of botulism toxin designated by the letters A through G; only types A, B, E and F cause illness in humans. Type A is the main cause of outbreaks in USA, China, and Argentina, whereas type B is involved in most outbreaks in continental Europe. In the following only the name *Clostridium botulinum* will be used for all types of clostridia causing botulism.

A detailed study of botulism was first published in the early nineteenth century in Germany by Kerner. He documented 234 cases of botulism that resulted in 119 deaths. He identified blood- and liver sausages as the predominant causes. The microorganism responsible for toxin production was identified some decades later and the toxin was isolated in the early twentieth century. Clarification of the protein nature of the toxin and determination of its chemical structure was a result of investigations in the period 1940 to 1970.

2.2. Growth and Toxin Production

The main factors that influence growth, and simultaneously toxin production, are the nutrient content of food, the moisture and salt content, the pH, the added preservatives, competing microflora, temperature and time of storage. Generally the growth of clostridia is controlled by several interacting factors. In Europe and many other countries the foods most frequently implicated were meats, meat products and fish, so the role of sodium chloride concentration and moisture was thoroughly investigated in such foods. It was confirmed that salt is the most important factor in the control of food-borne *C. botulinum*. Its effect is based primarily on the depression of the water activity.

In foods the growth-limiting water activity is about 0.94 to 0.97 which corresponds to a sodium chloride concentration of about 10%.

A pH near neutrality (the pH of meat and meat products, fish, mushrooms, vegetables) favors *C. botulinum*. It is generally true that most clostridia do not grow and produce toxins.

Of the preservatives used in pactice, nitrite should be first mentioned. Inhibition of *C. botulinum* with nitrite is well documented, particularly in cured meats. Its effectivity depends on the salt concentration and may be enhanced by addition of ascorbate. Interactions of nitrite with amines or amides of the meat to form N-nitroso compounds have generally led to regulations limiting either the input or the residual level of nitrites. *Nisin* (an antibacterial agent produced by some lactic acid bacteria) is used as a general anticlostridial agent in a number of foods, mostly dairy products.

As for temperature, due to the importance of storage at low temperatures, both minimum growth temperature and upper limits have been carefully investigated. A temperature as low as 10 ^{o}C and an upper value of 40 to 50 ^{o}C is generally accepted.

Competitive microflora may also play a role in the control of clostridia. In practice, starter cultures of certain strains of lactic acid bacteria are used in production of some type of sausages.

2.3. The Toxin

The toxins produced by *C. botulinum* are the most potent known—they are so powerful that a very small amount is sufficient to cause death. The botulinal toxins are proteins and they can exist in four molecular sizes with molecular weights varying from 150,000 to 900,000 Daltons. An important characteristic of the toxin is its comparatively low thermostability. Thus the toxin may be inactivated by heating. In laboratory experiments a treatment at 80 ^{o}C for 30 minutes is satisfactory for full inactivation, but it is recommended that suspect foods be kept at a full boil for at least 15 minutes.

2.4. The Disease

The disease has been thoroughly studied. Incubation period (the time between ingestion of toxin-containing food and observation of symptoms of intoxication) may vary from a few hours to several days; in most cases the first symptoms develop within 12 to 36 hours. These are generally nausea and vomiting, followed by a number of mostly neurological signs and symptoms.

Such symptoms may be visual impairments, blurred or double vision, paralysis of the motor nerves, slow pupillary reaction to the light, dilated pupils, etc.), loss of normal mouth and throat functions, fatigue with lack of muscle coordination, general muscle weakness, respiratory impairment. Gastrointestinal symptoms other than nausea and vomiting may also occur. Before antisera and modern respiratory support systems became generally available, fatality rates were about 50% or higher. At present they are 5 to 15% in most countries.

2.5. Control of *C. botulinum* in Foods

Generally, the preservation of high-moisture foods is geared primarily towards controlling *C. botulinum,* which also assures destruction of other pathogens. The type of treatment and its conditions are dependent on the food to be preserved. Thermoprocessing is common in preservation of canned vegetables and meat products where salt and nitrite often contributes to the destruction of pathogens. Lowering of water activity and refrigeration as often used methods of preservation do not mean significant risk—when good manufacturing practice is applied—for botulism. However, certain products in food service may be hazardous (e.g. potato salad, vegetables in oils).

3. Staphylococcal Food Poisoning

Staphylococci are ubiquitous microorganisms . They can be found in the air, water, milk, sewage and also in animals, including humans. Of the numerous species belonging to the genus *Staphylococcus* the most important is *Staphylococcus aureus.* The sources from which the food poisoning staphylococci enter foods are, for the most part, human or animal. The nasal passages of many persons are laden with these organisms and they can be found on the skin. Staphylococci may cause mastitis of dairy cows and as a consequence may contaminate milk and milk products.

Foods that may be contaminated by staphylococci include cream-filled bakery products, meat, poultry, meat products, fish and fish products, milk and milk products, cream sauces, salads, puddings, custards, pies, and salad dressings. Despite this long list, the mere presence of staphylococci in foods may not be hazardous as favorable conditions are also required for the growth of the organisms to produce toxin.

Foods such as meat and milk that are naturally contaminated are seldom involved in food poisoning, primarily because these foods are contaminated with other competitive microorganisms. Staphylococci are not considered to be good competitors unless they outnumber the other microorganisms present.

3.1. The Disease

Staphylococcal food poisoning is caused by *enterotoxins* produced by several strains of this microorganism. Toxins have been isolated and their chemical structure determined. The toxins are low molecular weight proteins resistant to degradation by proteolytic enzymes of the digestive tract.

The major signs and symptoms of staphylococcal poisoning—vomiting and diarrhea—occur generally about three hours after ingestion of food containing enterotoxin. Not infrequently blood may be present in the stool. Among other signs, pains in the abdomen, headache, muscular cramping and sweating can be mentioned.

The duration is brief, usually a day or two, and recovery is normally uneventful and complete. Death from this type of food poisoning is uncommon, but it has occurred. The casualties reported have been children or older individuals with other complications.

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Bibliography

Angulo F.J. and St. Louis M.E. (1998). Botulism. In: Evans A.S. and Brachman P.S. (eds). Bacterial Infections of Humans. New York: Plenum, 131-53.

Doyle, M.P. (1989). Food-borne Bacterial Pathogens, Marcel Dekker Inc., New-York, Basel. [A book giving detailed descriptions of pathogens occurring on/in foods, including characteristics of microorganisms and the diseases they cause, and control measures].

Food-borne Infections and Intoxications. (2004) Molecular Nutrition Food Research 48(7),473-552. [An issue devoted to the recent problems and results in investigation of food-borne diseases.]

Hobs,B.C.-Roberts,D: Food Poisoning and Food Hygiene, Edward Arnold Publ., London, Melbourne, Auckland,

Kaferstein, F. Ten Golden Rules for Safe Food Preparation. Magazine of the World Health Organization. The golden rules provide simple advice on how to prevent food-borne diseases. The target audience is families].

Kerner, J. (1820). Neue Beobachtungen über die in Würtemberg so haufig vorfallenden tödlichen Vergiftungen durch den Genuss geraucherter Würste. C.F. Oslander, Tübingen, Germany. [A first detailed report about the occurrence of botulism].

Motarjemi, Y. and Adams, M. (2005). Emerging Food-borne Pathogens. CRC Press, Boca Raton. [A recent book about newly discovered food-borne pathogens including surveillance practices in USA and Europe].

Shapiro R.L., Hatheway C., Becher J., Swerdlow D.L. (1997). Botulism surveillance and emergency response: a public health strategy for a global challenge. JAMA 278: 433-5.

Shapiro R.L., Hatheway C., Swerdlow D.L. (1998). Botulism in the United States: A clinical and epidemiologic review. Ann. Intern. Med. 129: 221-8.

Biographical Sketch

Maria King obtained her M.Sc. degree in biochemistry at Budapest University of Technology and Economics (Budapest, Hungary) in 1983 and a Ph.D. in Biochemistry, Microbiology and Medical Sciences in the Institute for Biotechnology in Berlin (Germany) in 1986. She acted as senior scientist and later as head of the Department of Biochemistry at the Central Food Research Institute in Budapest. Since 1996 she has been a consultant in the International Centre for Genetic Engineering and Biotechnology of UNIDO, visiting scientist at the Department of Food Science and Technology at Cornell University and at the Department of Biochemisrtry and Microbiology at Rutgers University. At present she is acting as Senior Researcher in the Department of Biochemistry and Biophysics at Texas A&M University. The main fields of her research activity are connected with biochemistry and biotechnology of microorganisms.