1979

EC79-2304 Understanding Botulism

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Understanding

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EXTENSION WORK IN "AGRICULTURE, HOME ECONOMICS AND SUBJECTS RELATING THERETO,"
THE COOPERATIVE EXTENSION SERVICE, INSTITUTE OF AGRICULTURE AND NATURAL RESOURCES,
UNIVERSITY OF NEBRASKA-LINCOLN, COOPERATING WITH THE COUNTIES AND THE U.S. DEPARTMENT OF AGRICULTURE
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Understanding Botulism

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Botulism is a relatively rare type of poisoning caused by the microorganism *Clostridium botulinum (C. botulinum)*. This organism is distributed in land and water environments throughout the world. Consequently, many foods are naturally contaminated with *C. botulinum* spores.

The major cause of botulism is improperly processed home canned food products. *C. botulinum* produces heat resistant spores that are difficult to destroy during canning. Spores in themselves are not dangerous. However, if not destroyed, they may germinate, grow and produce a deadly toxin.

There are several types of botulism, although *foodborne botulism* is the most commonly reported. It is caused by ingestion of preformed botulinal toxin in contaminated food.

Infant botulism, first recognized in 1976, is caused by absorption of botulinal toxin produced within the intestinal tract of an infant after growth of ingested *C. botulinum* spores. As of December 1978, 21 states have reported a total of 98 cases. Honey has been implicated as a source of *C. botulinum* in several cases of infant botulism. Thus, it is recommended that honey not be fed to infants less than one year of age.

Wound botulism, the rarest form of botulism, results from production of botulinal toxin after growth of *C. botulinum* in an infected wound. The first reported case of wound botulism occurred in 1943. Since this time a total of 18 cases have been reported in the United States.

The toxins produced by *C. botulinum* are the most deadly known to man. Scientists estimate that one cupful (8 ounces) of this purified poison would kill all the people on earth. Although the occurrence of the disease is rare, large numbers of people have been poisoned in a single outbreak, such as a 1933 incident in the Soviet Union in which stuffed egg plant relish caused 230 cases of Type A botulism. Yet botulism occurs rarely. The total number of botulism deaths that occur annually in *all countries* is less than the deaths from auto accidents on any holiday weekend in *this country*.

History and Occurrence

Botulism probably accounted for the deaths of many of our ancestors, but it was not until 1793 that a well-recorded outbreak of "sausage poisoning" occurred in Wildbad, Wurttemburg (Germany).

Thirteen people were involved in the Wildbad outbreak; six of them died. It was widely accepted at the time that the poisonings were caused by Blunzen, or Schweinmagen, a type of blood sausage which was locally popular. Blunzen were made by filling pigs' stomachs with blood and other ingredients. Ends of the stomach were tied and the product preserved by boiling and exposing to wood smoke. After this treatment, the Blunzen were stored at room temperature for weeks.

We now know that *C. botulinum* can grow in a product such as Blunzen. Unfortunately, the discovery that bacteria cause botulism did not occur until 1896, more than 100 years after that outbreak of sausage poisoning.

After the outbreak in Wildbad, the number of reported sausage poisonings increased rapidly. During the early 1800's, a German physician-poet, Justinus Kerner, carefully studied the disease and published several monographs about it. As a result of his study, sausage poisoning was brought to the attention of the German medical profession. Kerner became so wellknown for his work that botulism is sometimes referred to as "Kerner's disease." The more common term, "botulism," comes from the Latin for sausage, botulus, and was coined in 1870 by Muller.

In recent times in the U.S., meat products, such as sausages, have rarely been associated with outbreaks of botulism. In fact, only about 5 percent of the recorded outbreaks in the U.S. have been associated with meat.

Before the cause of botulism was clearly understood, many substances were suggested as being responsible for the disease. For example, Kerner thought it was caused by a fatty acid which he termed "corpse acid." Other suggestions included prussic acid, pyroligneous acid from wood smoke, choline, copper, lead, creosote, various fatty acids, vegetable alkaloids, various molds, *Trichinella spiralis*, neuridine and most fantastic of all, *Aqua toffana*. The Romans supposed *Aqua toffana* to be a toxic substance secreted in the saliva of slaves tortured to death in the arena. Because the method of killing hogs in Wurttemburg was slow, it was suggested that *Aqua toffana* was produced in the hog's saliva and ultimately contaminated the animal's flesh.

The discovery that botulism is actually caused by a toxin-producing bacterium was made by Emile Pierre Marie van Ermengem in 1896. An outbreak in the Belgian village of Ellezelles was brought to the attention of van Ermengem, then a professor of bacteriology at the University of Ghent. His ensuing study provided the data on which the modern understanding of botulism is based.

van Ermengem determined that ham was the source of the poison in the outbreak. He isolated an organism from this ham and from the spleen of one of the men who had died. Subcultures of this organism produced toxin that was lethal to several animal species. Consequently, van Ermengem named the bacterium *Bacillus botulinus* (now called *C. botulinum)* because he believed this organism had caused the poisoning at Ellezelles and that this disease was identical to "sausage poisoning." Succeeding studies confirmed the observations of van Ermengem.

Botulism was first recognized in the United States in 1899. In the 79 years from 1899 to 1978, there were 778 outbreaks of botulism in the U.S. involving 2,019 individuals of whom 1,002 died, for a 50 percent mortality rate. The fatality rate has declined significantly in recent years. The case-fatality rate in 1978 of 5.2 percent was a modern low.

The decline in the case-fatality ratio of foodborne botulism from the 50 percent figure seen in the first 79 years of this century is due mainly to improved detection methods, more readily available antitoxin and, especially, mechanized ventilatory assistance.

Nebraska State Department of Health

Director,
Disease Control Division
(Office 471-2937)
Director,
Housing and Environmental Health
(471-2541)

One of the above will, in turn, call on CDC for necessary epidemiologic and lab assistance and order the antitoxin.

Food Involved

Home-canned foods caused 72 percent of the outbreaks in the 79-year period from 1899 to 1978. Less than 9 percent were attributed to commercially processed or canned food and the majority of these, 41 of 66, occurred before 1930. The types of food products involved in these outbreaks are listed in Table 2. The type of food processing responsible for 17 percent of the outbreaks is unknown.

Table 2. Food products causing botulism outbreaks 1899-1977.[a]

Product	Outbreaks	
	No.	Percent
Vegetables	151	54.3
Fish and fish products	41	14.7
Fruits	29	10.4
Condiments[b]	23	8.3
Beef[c]	8	2.9
Milk and milk products	5	1.8
Pork	3	1.1
Poultry	4	1.4
Others[d]	14	5.0
	278	100.0

[a]Includes only outbreaks in which the toxin type was determined. In two-thirds of the outbreaks the toxin type was not determined.

[b]Includes outbreaks traced to tomato relish, chili peppers, chili sauce, salad and dressing.

[c]Includes 1 outbreak of type F in venison, and 1 outbreak of type A in mutton.

[d]Includes outbreaks traced to ripe olives, spaghetti sauce, and to corn and chicken stuffing.

Vegetables are the major type of food involved in botulism outbreaks. Of the 278 outbreaks shown in Table 2, 151 (54.3%) were associated with vegetables. Fish was second with 41 outbreaks, followed by fruits, condiments, milk, pork, and poultry. In almost every instance, the foods involved had been canned or processed in some manner, stored for some time and then consumed.

Prevention

The major cause of botulism outbreaks is improperly processed home-canned food products. Prevention is simple; follow proper techniques when canning food in the home.

Listed below are U.S. Department of Agriculture publications on canning foods at home. Single copies of these publications are available free from the U.S. Department of Agriculture, Washington, D.C. 20250. Send your request on a post card. Include your zip code in your return address.

G 8 - Home Canning of Fruits and Vegetables
G106 - Home Canning of Meat and Poultry.

Several University of Nebraska extension publications about home-canning methods are available at county extension offices:

Home Canning Meat and Poultry HEG-76-19
Home Canning Fruits and Vegetables HEG-79-108.

Another good reference for the home canner is a free 100-page booklet entitled "Home Food Preservation." It is available by sending a post card to:

Consumer Protection Center,
Department 664G,
Pueblo, CO 81009.

"Home Canning" is the title of a scientific status summary prepared by the Institute of Food Technologists. Copies of this indepth review are available from the:

IFT Regional Communicator
Department of Food Science and Technology
116 Filley Hall
University of Nebraska-Lincoln
Lincoln, Nebraska 68583

A number of companies that sell home-canning supplies also have publications on home canning.

Ball Corporation
345 South High St.
Muncie, IN 47302

Bernardin Inc.
2201 W. Maryland
Evansville, IN 47705

Kerr Glass Manufacturing Corp.
Sand Springs, OK 74063

Mirro Aluminum Co.
Manitowac, WI 54220

National Presto Industries, Inc.
3924 W. Hastings Way
Eau Claire, WI 54701

More extensive advice on canning can be found in the following texts:

Farm Journal Editors. Freezing and Canning Cookbook. Rev. ed. Nichols, Nell B., ed. 1973. Doubleday.

Gaulke, Judith A. Home Canning. 1975. Lane Publishing Company.

Hold, Calvin and Caradine, Patch. A Guide to Canning and Preserving. (orig.) 1974. Pyramid Pub.

Home Canning by Better Homes and Gardens. Meredith Publishing Co., Des Moines, IA

The toxin or poison produced by *C. botulinum* is readily destroyed by heat. To inactivate toxin, bring food to a boiling temperature and hold that temperature for 10 minutes. A good rule to follow is *always boil homecanned vegetables before tasting them,* particularly if the vegetables in the container, when opened, have a bad smell, bubble or look different. "When in doubt,

Only in seven nations — the U.S., Poland, Germany, Union of Soviet Socialist Republics, Japan, France, and Canada — do faulty methods of preserving food in the home coincide with the presence of *C. botulinum*. Poland has more botulism than any other nation. Most of the outbreaks result from eating improperly home-canned meat.

Foodborne botulism outbreaks have been reported from 45 states since 1899. Five western states (California, Washington, Colorado, Oregon, and New Mexico) have accounted for more than half of all reported outbreaks.

Since 1899, there have been 10 outbreaks, 28 cases and 21 fatalities in Nebraska. The latest outbreak, the first since 1931, occurred in 1979; the incriminated food was home-canned tomatoes.

However, botulism remains a modern day problem. In 1978, twelve outbreaks of foodborne botulism, involving 58 cases, occurred in the United States. This compares with 80 cases in 1977 and an average of 7.9 outbreaks, with 18.7 cases per year, from 1970 through 1976.

History of Scientific Methods for Home Canning

The first instructions for home canning were printed in the United States in the nineteenth century. Most of these instructions, developed through hit or miss techniques, incorporated the procedures developed by Nicholas Appert, a French chef in Napoleon's time. Many cookbooks of the Victorian era contained home canning instructions as well as descriptions of the difficulty of preserving some foods using these methods.

During World War I, the first United States government publications on home canning were printed. These publications were part of a massive campaign to urge citizens to grow and preserve their own food. They contained directions for many extremely dangerous canning methods such as water bath and steam processing of low-acid vegetables, as well as oven canning. The net result of this campaign was that many Americans died of botulism from under-processed homecanned vegetables.

In 1943, the United States Department of Agriculture (USDA) issued a firm statement that pressure canning was the only safe way to can meat and low-acid vegetables. In 1946, the USDA published results of the extensive heat penetration and bacteriological studies on home-canned foods and established a scientific basis for home-canning instructions.

The first reexamination of USDA home-canning recommendations since 1945 was completed in 1978 at the University of Minnesota. The results of these studies have been published in University of Minnesota Extension Bulletin 413 "Home Canning—Fruits, Vegetables, and Meats." While some of the times and temperatures in this bulletin are different from those of the USDA, the new times and temperature combinations are safe and give quite reliable results.

The Organism and its Classification

C. botulinum includes several types or strains of bacteria that produce neurotoxin differing in chemical makeup and antigenicity. However, organisms so classified are alike in that they are:

1. Rod shaped (2 to 10 um in length and 0.5 to 2 um in width).[a/]
2. Anaerobic (grow in the absence of oxygen).
3. Form spores (very resistant, dormant or resting form of a bacterium).
4. Produce neurotoxins (toxins that affect the nervous system) with similar pharmacological action.

[a/] One um equals 1/25,400th of an inch.

Table 1. Types of Clostridium botulinum and animals more commonly affected by the toxins produced.[a/]

Type	Species
A	*Man*
B	*Man*, horse
C alpha	Birds, turtles
C beta	Cattle, sheep, horses
D	Cattle, sheep
E	*Man*, birds
F	*Man*
G	No recognized outbreaks

[a/] Types A, B, E and F cause botulism in man with Types A and B occurring most frequently in the United States. Type A is the predominant type in the western U.S., whereas Type B is the prevalent type in the eastern U.S. Type E occurs most often with seafoods, particularly ethnic seafoods of the Eskimos and Native Americans of the Northwest. It has been reported that Types C and D each have caused one or two cases of botulism in man.

RESISTANCE TO HEAT

C. botulinum has the ability to form an entity called a spore (oval in shape with a diameter of 2 um). A spore is a dormant or inactive form of the cell and must germinate to become a actively growing cell, capable of producing toxin.

The spore is the most efficient survival mechanism in nature. Spores are very resistant to adverse conditions such as heat, chemical treatments, physical stress and other environmental changes. For example, under proper conditions, spores of *C. botulinum*, Types A and B, will survive from 5 to 6 hours at 212 °F (100 °C). Fortunately, at higher temperatures, much less time is required to destroy these spores, and this is recognized in the canning or "commercial sterilization" of food. For example, at 250 °F (121 °C), low-acid food will be sterilized in only 3 minutes; in ultrahigh-temperature food processes, a heat treatment of a few seconds at 280 °F (138 °C) is sufficient to destroy spores of *C. botulinum*.

The heat resistance of *C. botulinum* spores is one reason why outbreaks of botulism are usually associated with homecanned, preserved, or processed foods. Spores may survive in insufficiently processed food. During subsequent food storage, these spores may germinate into actively growing bacteria and produce toxin.

A less severe heat treatment is needed to destroy the toxin than is necessary to kill the spores. Heating food to boiling for 10 minutes will destroy botulinal toxin. If contaminated food is eaten without sufficient heat treatment to destroy the toxin, severe illness and possibly death will occur.

Growth Requirements

The requirements for growth of *C. botulinum* are:

1. A food contaminated with *C. botulinum* and capable of sustaining its growth.

2. *An absence of oxygen.* Strict anaerobic conditions; only Type E does *not* require strict anaerobic conditions for growth.

3. *Proper temperature.* A range of 50°F (10°C) to 118°F (47.7°C) for Types A and B or as low as 38°F (3.3°C) for Type E.

4. *A pH greater than 4.5.* "Low-acid" foods; i.e., vegetables and meats.

5. *A low salt concentration.* 5 to 10% brine (% brine equals % NaCl divided by % NaCl + % H_2O multiplied by 100).

6. *Water activity (Aw) greater than 0.85.* An expression of water available (Aw = vapor pressure of food divided by vapor pressure of pure water).

Improperly canned foods, primarily low-acid vegetable products, provide excellent growth conditions for *C. botulinum*. When food is canned, the air is either evacuated or driven out, thereby creating anaerobic conditions necessary for the growth of *C. botulinum*. Further, the spores of *C. botulinum* are more heat resistant than the vegetative forms of other bacteria. Consequently, spores of *C. botulinum* may remain as the sole survivors in improperly canned food.

Both meat and vegetable items provide the nutrients needed by *C. botulinum* for growth. Most of these foods are low acid (pH greater than 4.6) and can support the growth of this organism. High-acid foods require a milder heat treatment than low-acid foods because *C. botulinum* will not grow at a pH of 4.6 or less. Nevertheless, a number of outbreaks of botulism have been caused by "high-acid" foods.

Cured meats were commonly associated with botulism in the past century. This is no longer true in the U.S. because of the sophisticated and carefully controlled processes used by the modern meat industry.

A number of factors are used to preserve cured meats. During processing, most cured meats are cooked, which eliminate vegetative bacteria but not the more resistant spores. Cured meats, unlike canned foods, usually cannot be heated to the extent necessary to destroy all spores of *C. botulinum* because product quality would be reduced. Thus, to prevent the growth of botulinal spores which may survive in cured meat, inhibitory agents, namely salt and nitrite, are added. A combination of other factors, including good sanitation (and therefore low numbers of *C. botulinum*), a relatively low pH and refrigeration of perishable products, are also used to prevent botulism in cured meats.

The combined effects of these factors are of practical importance in the preservation of food. Lowering the pH or raising the salt concentration increases the minimum temperature at which *C. botulinum* grows. Similarly, increasing the acidity of a food decreases the maximum salt concentration at which growth starts.

In general, prevention of foodborne botulism is accomplished either by using heat *to destroy C. botulinum* spores in a food ("commercial sterilization") or by using a combination of factors *to prevent growth of C. botulinum* in the food.

The Disease

Foodborne botulism is almost always caused by eating improperly preserved food in which *C. botulinum* has grown. Reports of botulism deaths from eating a single string bean or a few kernels of home-canned corn are not uncommon. In one instance, an individual died who had taken a mouthful of home-preserved peppers but spat them out.

One of the most notable outbreaks of botulism in the U.S. killed an entire family of 12. The outbreak, which occurred in Albany, Oregon in 1924, involved home-canned string beans.

Whatever food is responsible, the pattern of the disease is generally the same. After ingestion, the toxin is absorbed and carried by the blood to the nerves. Nausea and vomiting are often (56% of U.S. cases) the first symptoms to appear. These particular symptoms are probably caused by contaminants other than the botulinal toxin.

Early signs are a tired or weak feeling and dizziness. Double vision, inability to focus, and progressive difficulty in speaking and swallowing almost always occur and are due to the effect of the neurotoxin on nerve transmission.

Individual resistance to the toxin varies widely. Symptoms ordinarily appear in 18 to 36 hours, although in one instance it was as short as 2 hours. There are also cases on record in which the latent period was as long as a week. Variability in the time of onset from eating contaminated food can be accounted for by the dose and time required for absorption of the toxin.

As the disease progresses, there is increasing paralysis due to the action of the botulinal toxin in preventing the passage of stimuli from the motor nerves to the muscles. Eventually, muscles fail to respond to their specific stimuli until the muscles needed for breathing or the cardiac muscles of the heart falter and fail.

CDC - Emergency Assistance

Because botulism is a rare disease, most physicians probably do not see a case of botulism in a lifetime of practice. This often results in misdiagnosis. The Center for Disease Control (CDC), Atlanta, Georgia 30333, distributes to physicians and other interested individuals information concerning the diagnois of botulism and the use and availability of botulinum antitoxin (at no cost) in an effort to aid in the early diagnosis and treatment of botulism. Ask for *Botulism in the United States, 1899-1977: Handbook for Epidemiologists, Clinicians and Laboratory Workers.*

Prompt diagnosis and early treatment of botulism are essential to minimize the otherwise great risk of death due to botulism. When a diagnosis of botulism is considered, the physician should contact The Center for Disease Control (Day phone) - (404) 329-3753 or (Night phone) - (404) 329-3644. Equally important is the need to identify the offending, contaminated food source and remove it so others won't partake of it and fall ill; and to test it for botulinum toxin. Epidemiologic investigation and disease control are statutorily the responsibility of the local health department, where one exists, and, where not, that of the State Department of Health. Following is a list of state personnel by office and phone numbers:

throw it out!"

The habit of tasting homecanned vegetables before they are cooked almost cost one woman her life in South Bend, Indiana. The woman became ill one day and became progressively sicker as the days went on. Finally, 5 days after her initial symptoms appeared, botulism was considered and antitoxin therapy started. Her condition had been diagnosed as viral encephalitis, idiosyncratic reaction to prochlorperazine and myasthenia gravis. She recoved a full 8 days after botulinum antitoxin therapy was started.

The interesting part of this outbreak was that the woman shared all her meals with two other individuals, neither of whom became ill. They quite often consumed home-canned vegetables that were fully cooked at their meals. But, the woman had the habit of tasting the home-canned vegetables prior to cooking and this probably explains why she became ill and none of the others did.

Food canned in the home under proper conditions for the type of food involved will be safe to eat. Problems only develop when improper canning techniques are used.

Commercially canned products are safe to eat if the can ends are not bulged and if the product appears normal and has a normal odor.

Bulging can ends and jar lids usually indicate spoilage. If it becomes necessary to dispose of canned foods, do it in such a way that there is no chance that they will be eaten by humans or animals.

Spoilage of commercially canned food items should be promptly reported to the Food and Drug Administration by telephone or mail. Information in such a report should include:

1. The nature of the problem involved.
2. A detailed description of the product's label.
3. Any code marks embossed or stamped on the lid of the can.
4. The name and address of the store where the product was bought.
5. The date of purchase.

In Nebraska, such reports should be directed to:

Chief Resident Inspector
or
Consumer Affairs Officer
Food and Drug Administration
1619 Howard Street
Omaha, NE 68102
(402) 221-4675(6)

Commercial outlets for prepared foods, such as grocery stores, delicatessens and restaurants, may serve as a source of contaminated food. These are under jurisdiction of the Nebraska State Agriculture Department and are automatically involved by the State Epidemiologist when the latter receives a report of a human case of botulism.