Clostridium Botulinum – the priority organism

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By Eben van Tonder

Introduction

Removing nitrite from bacon production is to remove an important hurdle against Clostridium botulinum. We examine the bacteria, its toxicity and prevalence and start looking at a suggested system of alternative barriers to the use of nitrite.

Background

Botulism is a serious and potentially fatal disease. It is caused by a toxin called botulin, a neurotoxic proteins produced by the bacteria Clostridium botulinum. It is so poisonous that one millionth of a gram can kill an adult human. 500mL is enough to kill every person on earth. (Sterba, J. P.; 28 April 1982)

Clostridium botulinum is a rod-shaped bacterium which is common in soils worldwide and feeds on dead and decaying organic matter. “The bacteria themselves are not toxic when ingested, and they are commonly consumed on fruits, vegetables and seafood.” (Sterba, J. P.; 28 April 1982)
The toxin is produced when the bacteria reproduce under certain conditions. (Sterba, J. P.; 28 April 1982)

Infections through food occurs in two ways. Either by eating food contaminated with the toxin or by intestinal colonisation as a result of eating food contaminated by c. botulinum and toxin formation intestinally and absorption into the blood stream. (Simjee, S.; 2007: 41) “From there it moves quickly to attack the nervous system, causing paralysis that begins to exhibit itself in anywhere from 12 to 36 hours. The symptoms can include vomiting, nausea, blurred vision and difficulty in swallowing.” (Sterba, J. P.; 28 April 1982)

What happens in the nervous system is that the botulin inhibits the body’s production of acetylcholine, the chemical that produces a bridge across synapses, where nerve cell axons and dendrites connect with each other. (Sterba, J. P.; 28 April 1982)

An important case of botulism relates to the Bon Vivant Company of Newark, New Jersey, and its vichyssoise (cold potato soup). More than 6000 cans of soup were found to be contaminated by botulism endospores that came into the cans through contaminated dirt. The Food and Drug Administration (FDA) of the USA investigated and found that the cans were not properly heated during the cooking process. In June 1971, Samual Cochran, Jnr., vice president of the Bank of New York, died after eating this soup. His wife, Grace, became severally ill, but survived. (Emmeluth, D.; 2010: 11)

The Bon Vivant indecent had an important consequence of widening the scope of a food-safety movement from the 1960’s. The initiative was started to ensure safe foods for the astronauts to be consumed in space. It came to be known as Hazardous Analysis Critical Control Points (HACCP). It eventually had the support of industry, the regulators and the the scientific community. It was the Bon Vivant incident that became the impetus for extending the NASA initiative to the general food processing industry around the world in order to ensure safe food for all people and not just astronauts.

Overall, Botulism is not very common. On average, around 100 cases is reported in the USA each year. Nearly 75% occurs in infants. Only 25% are attributed to food poisoning. The issue is that it is deadly and the low occurrence can not impact on our considerations. (Emmeluth, D.; 2010: 15)
History

Justinus Kerner was the medical officer in southern Germany, in Württemberg between 1817 and 1822. Over time he identified a set of symptoms from people who got sick from eating sausages that were not properly cooked. This included impaired breathing, difficulty in speaking, swallowing and seeing double. He suspected a type of biological poison was at work. (Emmeluth, D.; 2010: 16)

He published a complete description of what he called “sausage poisoning” or wurstgift between 1817 and 1822. (Emmeluth, D.; 2010: 16) The Latin word for sausage is "botulus" (Sterba, J. P.. 28 April 1982) and the disease came to be known as botulism. “He injected himself with the poison and caused many of the symptoms in himself. Luckily he survived, but he managed to show conclusively the causal relationship between the sausage material and the disease.” (Emmeluth, D.; 2010: 16, 17)

Clostridium botulinum was isolated as the microorganism causing botulism in 1895 by Emile Emergem, professor of bacteriology at the university of Ghent, in Belgium. (Emmeluth, D.; 2010: 19)

Emile was called when in 1897 a botulinum outbreak occurred after a funeral dinner where smoked ham was served as the main course. (Emmeluth, D.; 2010: 19) He studied under Robert Koch, the father of bacteriology (1) and used the techniques taught him by Koch to identify the bacteria as the causative agent of the food poisoning. (Emmeluth, D.; 2010: 28, 29)

Characteristics

A rod or pencil shaped bacterium is called a bacillus (bacilli, plural). The botulism organism is such a rod shaped organism. (Emmeluth, D.; 2010: 32)

It is a strict anaerobe. Anaerobic organisms are ones to whom oxygen is toxic or lethal. Clostridium botulinum is a strict or obligatory anaerobe because it can not tolerate any oxygen. (Emmeluth, D.; 2010: 32)

This is important due to the fact that when we vacuum pack bacon, we remove the oxygen, thus creating an ideal environment for c. botulinum from an oxygen perspective. If we would
sell the bacon frozen, one of the barriers may be to include an instruction to open the package after thawing in order to allow oxygen in. Another option is not to remove all the oxygen during packaging which of course will have serious shelf life implications if sold chilled.

A limited number of bacteria have the ability to form a highly resistant survival structures called endospores. C. botulinum is one of these organisms. C. botulinum is a common soil bacteria, found worldwide, but when dormant, as endospores, these are easily spread through the air and contaminate a variety of areas.

This dormant structure is formed inside the individual bacteria and is resistant to most extreme environmental factors such as temperature (heat and cold), desiccation (dehydration), chemicals, radiation, pressure, extremes of pH, and common dyes. Remarkably, some endospores have been dormant for 25 million years preserved in amber only to be shaken back to life when removed and placed in favourable environments again. (Emmeluth, D.; 2010: 34) These conditions that an endospore is resistant to are also the techniques used to preserve meat.

The other organism that is important to us that form spores is the genus *bacillus*.

**Types of neurotoxins**

Clostridium botulinum is a genetically diverse species. Within the species are slight genetic differences which allow certain groups to produce different types of toxic proteins. (Emmeluth, D.; 2010: 37)

There are seven distinct types of these toxins, each designated by the letter A through G. All seven are neurotoxins meaning that they affect the nervous system. Each toxin is distinct meaning they can be used as marker to identify the cause of the botulism. Other species have strains that can produce botulinum toxins. These species include *Clostridium baratti*, *Clostridium butyricum*, *Clostridium argentinense*. (Emmeluth, D.; 2010: 37)

Type A is the most lethal. Type A, B, E and occasionally F cause human disease. Type A, B and F are able to break down proteins and are called proteolytic. When they break down protein, there is often a foul odor which will serve as a warning for bacterial contamination.
This is also important for bacon production since bacon is normally sold without any flavours added that can potentially mask the smell. Non-potentially type such as B is able to grow under refrigeration and do not give a foul odor, but their spores are of low heat resistance (Emmeluth, D.; 2010: 38)

**Sources of botulism**

In the USA, most outbreaks of botulism has been attributed to improperly home canned foods, mostly fish and low acid vegetables. In children under 1 year old, honey has also been an implicated food. (Emmeluth, D.; 2010: 44)

Below is a diagram that lists the foodborn botulism cases in the USA between 1990 and 2000 as well as the products involved. (Simjee, S.; 2007: 50)

<table>
<thead>
<tr>
<th>Food type</th>
<th>Incidents</th>
<th>Cases</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noncommercial home-canned vegetables</td>
<td>47</td>
<td>70</td>
<td>Likely to be weak acid foods (pH &gt;4.6). Asparagus (9 incidents, 14 cases) and olives (4 cases) were the most common vehicles. Also includes two episodes with garlic in oil which was insufficiently heated to kill <em>C. botulinum</em> spores</td>
</tr>
<tr>
<td>Noncommercial home-prepared meat products (sausage, pate, beef chilli, meatballs, roast beef, hamburger)</td>
<td>7</td>
<td>9</td>
<td>Sausages (3 cases) were the most common vehicle. Failure to refrigerate beef chilli after cooking associated with two cases</td>
</tr>
<tr>
<td>Noncommercial home prepared other products (salsa, potato salad, bread pudding, soup, apple pie, potatoes, and pickled herring)</td>
<td>14</td>
<td>18</td>
<td>Soup (4 cases) of unspecified type was the most common vehicle. Salsa was responsible for 2 cases and was prepared from raw vegetables and stored at room temperature in an airtight plastic container</td>
</tr>
<tr>
<td>Commercial (preserved fish, burrito, and bean dip)</td>
<td>5</td>
<td>10</td>
<td>All outbreaks involved poor handling practices</td>
</tr>
<tr>
<td>Restaurant made (cheese sauce and skordalia)</td>
<td>2</td>
<td>25</td>
<td>One outbreak (17 cases) was associated with skordalia which involved potatoes baked in aluminium foil and left at ambient temperature for several days. The second outbreak (8 cases) involved a cheese sauce which was left unrefrigerated</td>
</tr>
</tbody>
</table>
Contamination to clostridium botulinum has mainly been linked to home prepared foods from its earliest identification and food where proper food handling has not been practiced.

Between 1990 and 2000 there has been no outbreak associated with pork.

In the European Union (EU), between 2006 and 2008, there has been 477 confirmed cases of botulism with an average of 119 cases per year.

The trends from the US are also present in the European Union.

Eurosurveillance, Volume 16, Issue 49, 08 December 2011 lists the following sources for the outbreaks.

- Food-borne botulism is caused by the ingestion of toxin produced by organisms in an anaerobic environment. It usually results from inadequately sterilised domestically canned or bottled foods.
- Intestinal botulism is caused by the production in the gut of toxin by organisms which have been ingested and have proliferated. This form predominantly affects infants under a year old, often associated with the consumption of honey.
- Wound botulism is caused by the production of toxin by organisms introduced into wounds. This is often associated with dirty wounds, including those following injecting drug use.

They describe botulism as a severe disease that can be fatal in 5-10% of cases. (Eurosurveillance)

Below is an analysis of the incidences of botulinum in the UK between 1922 and 2002. Notice the variety of products as well as the type of toxin. (Simjee, S.; 2007: 51)
Evaluating the data from 1922 to 2002, one can see that there has been no outbreak associated with pork in the UK, with one possible exception being one case in 2002 related to sausage from Poland. Column 4 gives the implicated foods from the time under review as duck pâté, rabbit and pigeon broth, juggled hare, vegetarian nut brawn, minced pie, macaroni cheese, pickled fish from Mauritius, canned salmon from the USA, rice and vegetable shelf stable airline food, hazelnut yogurt, bottled mushrooms from Italy and sausage from Poland.

<table>
<thead>
<tr>
<th>Year</th>
<th>Cases (Deaths)</th>
<th>Home-prepared</th>
<th>Implicated food (Country of origin, if outside the UK)</th>
<th>BoNT type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1922</td>
<td>8 (8)</td>
<td>No</td>
<td>Duck pâté</td>
<td>A</td>
</tr>
<tr>
<td>1932</td>
<td>2 (1)</td>
<td>Yes</td>
<td>Rabbit and pigeon broth</td>
<td>NK</td>
</tr>
<tr>
<td>1934</td>
<td>1 (0)</td>
<td>Yes</td>
<td>Jugged hare</td>
<td>NK</td>
</tr>
<tr>
<td>1935</td>
<td>5 (4)</td>
<td>Yes</td>
<td>Vegetarian nut brawn</td>
<td>A</td>
</tr>
<tr>
<td>1935</td>
<td>1 (1)</td>
<td>Yes</td>
<td>Minced meat pie</td>
<td>B</td>
</tr>
<tr>
<td>1949</td>
<td>5 (1)</td>
<td>Yes</td>
<td>Macaroni cheese</td>
<td>NK</td>
</tr>
<tr>
<td>1955</td>
<td>2 (0)</td>
<td>NK</td>
<td>Pickled fish (Mauritius)</td>
<td>A</td>
</tr>
<tr>
<td>1978</td>
<td>4 (2)</td>
<td>No</td>
<td>Canned salmon (USA)</td>
<td>E</td>
</tr>
<tr>
<td>1987</td>
<td>1 (0)</td>
<td>No</td>
<td>Rice and vegetable shelf stable airline meal</td>
<td>A</td>
</tr>
<tr>
<td>1989</td>
<td>27 (1)</td>
<td>No</td>
<td>Hazelnut yoghurt</td>
<td>B</td>
</tr>
<tr>
<td>1998</td>
<td>2 (1)</td>
<td>Yes</td>
<td>Bottled mushrooms (Italy)</td>
<td>B</td>
</tr>
<tr>
<td>2002</td>
<td>1 (1)</td>
<td>Yes</td>
<td>Sausage (Poland)</td>
<td>B</td>
</tr>
</tbody>
</table>

NK, not known.
Based on ref. (140,151).

Evaluating the data from 1922 to 2002, one can see that there has been no outbreak associated with pork in the UK, with one possible exception being one case in 2002 related to sausage from Poland. Column 4 gives the implicated foods from the time under review as duck pâté, rabbit and pigeon broth, juggled hare, vegetarian nut brawn, minced pie, macaroni cheese, pickled fish from Mauritius, canned salmon from the USA, rice and vegetable shelf stable airline food, hazelnut yogurt, bottled mushrooms from Italy and sausage from Poland.

**Botulism and bacon production**

The use of nitrite as curing agent has been controversial and health concerns existed right from the start. Removing it removes an important barrier against clostridium botulinum. The question arises if the production of a nitrite free bacon places the public at risk. A second important consideration is if an alternative to nitrite exist as a barrier against it.

- **Many other foods that can be contaminated with c botulism is not treated with nitrite**

The debate about removing nitrite from bacon is often an emotional one. Proponents of its continued use pitch it as a choice between the potentially deadly toxin and a disputed claim that nitrite leads to increased risk of cancer. The emotion is removed from the argument by firstly realising that many other food’s where clostridium botulinum can occur is not treated with nitrite. Not using nitrite as a hurdle is something that is currently being done in the majority of foods that we regularly consume.
It is impractical or undesirable to treat most potential carriers of clostridium botulinum with nitrite. It is similarly impractical and undesirable to treat many of these foods in any way that will eliminate all clostridium botulinum spores.

With this in mind, it does not make sense to treat the removal of nitrite from bacon production as something that can be done only if a single ingredient is found to replace nitrite as far as its efficacy as a hurdle against c. botulism is concerned.

- **Other pork products are sold regularly with long shelf lives, not treated with nitrite**

A second point that must be made when considering the removal of nitrite from bacon is that in South Africa, as in many other places around the world, cooked spare-ribs, marinated or unmarinated are sold without nitrite and with long shelf lives. If bacon can not be sold without nitrite, then the entire spare-rib industry must be re-examined.

- **Control measures to consider**

A single product to replace nitrite has not been found as far as it relates to colour development, acting as a barriet against clostridium botulinum, preventing rancidity of fats and off flavour development and delivering a "cured taste".

A combination of CCP’s and functional ingredients has the potential of effectively replace nitrite.

The main limiting factors for growth of clostridium botulinum in foods are: temperature, pH, water activity, redox potential, food preservatives, and competing microorganisms. All of these factors are interrelated and so changing one factor influences the effect of other factors. The interaction of factors may have a positive or negative effect on the inhibition of C. botulinum.” (Botulism in the United States, 1899 – 1996: 6)

The control measures are readily identifiable from the table of characteristics of the C. Botulinum Groups given below ((Simjee, S.; 2007: 43).
Suggested combination of hurdles if nitrite is removed

Let's remind ourselves again that type A is the most lethal. Type A, B, E and occasionally F cause human disease.

We now begin to consider the suggested hurdles and what can be done in order to make the hurdles CCP’s.

a. pH < 4.6 – prevent growth and toxin formation by C. botulinum types A, B, E, and F.

(UCM252416)

– adding acetic acid to the brine in a fixed amount to drop brine pH to required level.
– measure pH in meat from every injection batch to verify that the meat pH is < 4.6.
– tumble the meat in order to ensure proper diffusion of brine through meat to prevent acid pockets or pockets with pH > 4.6.
– measure pH of every batch after tumbling.

The challenge is correcting the meat colour.
b. Controlling the amount of moisture that is available in the product (water activity) to 0.85 or below by drying, to prevent growth and toxin formation by C. botulinum types A, B, E, and F and other pathogens that may be present in the product.  (UCM252416)

This will be accomplished in combination between the % salt, functional ingredients that accomplish water binding and drying during the heating process.

Verification will be done through testing per batch.

The list below indicates that bacon should fall in the category of aw of < 0.87.  (Fundamentals of water activity: 8)
c. Controlling the amount of salt in the product to 20% water phase salt (wps) or more, to prevent the growth of C. botulinum types A, B, E, and F and other pathogens that may be present in the product. This will be calculated as follows per batch: \((\% \text{ NaCl } \times 100)/(\% \text{ NaCl } + \% \text{ moisture}) = \% \text{ NaCl in water phase}\). (UCM252416)

Alternatively, if the % moisture can not be determined empirically, the value will be derived from the following table from the water activity. (UCM252416)

![Relationship of Water Activity to Water Phase Salt in NaCl/Water Solutions](image)

d. Cold Smoking Temperatures. Achieve internal core temp > 62.8 deg C for at least 30 mins. (UCM252416)

e. Introduce a combination of lysozyme and nisin as a preservative in the brine at levels that has proven efficacy against toxin formation of c. botulinum. (UCM252416)

Unintentional consequences

An important unintentional consequence of an application of the above method is that the safety of the products produced under these conditions will generally be improved.

Conclusion

Managing the risk of clostridium botulinum is possible in the bacon industry without the use of nitrite. It is achieved by employing various barriers in combination.
"Bacon & the art of living" in book form

Notes:

1. Koch won the Nobel prize for physiology or medicine in 1905 for his body of work on tuberculosis and the methods for confirming its presence. (Emmeluth, D.; 2010: 29)

References


Eurosurveillance, Volume 16, Issue 49, 08 December 2011
