### Growth of *Clostridium botulinum*

*Clostridium botulinum* spores are **ubiquitous** in the environment. They are found in the soil and have been recovered in agricultural products such as honey. Spores are also found in marine sediments and the intestinal tracts of animals. The spores are highly **resistant** to inactivation. As a result, control methods for botulism focus on inhibiting the organism's growth and toxin production, rather than treating the food product to eliminate the spores. The primary factors limiting growth (and toxin production) of *C. botulinum* are:

<table>
<thead>
<tr>
<th>Factor</th>
<th>Description</th>
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<tr>
<td><strong>Temperature</strong></td>
<td>The optimal growth temperature for most strains of <em>C. botulinum</em> is around 40°C (104°F). Some strains, however, can grow even at 3°C (37°F), which is lower than ordinary refrigeration.</td>
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<td><strong>pH</strong></td>
<td>pH is a measurement of the acidity or alkalinity of a substance. A pH of 7 is considered neutral, a pH of less than 7 is acidic, and a pH of greater than 7 is alkaline. Typically, <em>C. botulinum</em> will not grow in a pH below 4.6. Some food proteins (such as soy and beef), however, may have a protective effect on <em>C. botulinum</em> and allow it to grow at a lower pH.</td>
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<tr>
<td><strong>Water activity</strong></td>
<td>Water activity is a measurement of the amount of moisture in a substance that is available for a microorganism to grow. In foods, dehydration or the addition of NaCl (i.e., table salt) decrease the water activity and, therefore, microorganism growth. <em>C. botulinum</em> requires a water activity of at least 0.94 to grow and produce toxin. This water activity n s corresponds to a salt solution of 10% or less.</td>
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### Redox potential

The redox potential reflects in part, the **amount of oxygen in the environment**. The higher the oxygen content is, the higher the redox potential. Because *C. botulinum* is an anaerobic organism, it cannot grow in the presence of oxygen and requires a low redox potential. Vacuum packaging lowers the redox potential and so *may* support the growth of *C. botulinum* and the production of toxin.

### Food preservatives

Several food preservatives (e.g., nitrite, sorbic acid, parabens, phenolic antioxidants, and ascorbates) inhibit the growth of *C. botulinum* and limit toxin production.

### Competing organisms

Lactic acid bacteria such as *Lactobacillus, Pediococcus,* and *Lactococcus* have been shown to produce acid. The resulting lower pH inhibits *C. botulinum* growth.

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All of these factors are interrelated, so changing one might influence the effects of the other factors. Certain foods are classically associated with botulism such as home canned vegetables in the U.S. and sausages in Germany. If the right conditions exist, however, *C. botulinum* can grow and produce toxin in any food. New and unexpected vehicles for botulism are discovered every year. For instance: Chopped garlic was found to be the source of an outbreak of botulism in Vancouver, British Columbia in 1985.

This outbreak is described in the Explore with an Expert, *Diagnosis of Botulism.* *(St. Louis ME et al. 1988)* Although garlic was a new vehicle for botulism at the time, the finding, perhaps, was not so surprising:

- Garlic is a tuber grown in soil (and soil contains an abundance of *C. botulinum* spores).
- The implicated garlic was cooked lightly (but not sufficiently to inactivate botulism spores) and coated with soybean oil (producing a relatively anaerobic environment).
- The resulting product had a pH above 4.6, which is the minimum pH for *C. botulinum* growth.
- In addition, the garlic implicated in the outbreak was stored at room temperature, which is well within the growth range for botulism.

As a result of this outbreak and a subsequent one, commercially chopped garlic is now required to be acidified, usually with phosphoric acid, in order to prevent botulism. No further outbreaks from commercially chopped garlic have occurred since this requirement was enacted.
The "Reference" files are not included in the *Alternative Package* of the case study.