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Canning: Appert and Food Canning

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Appertization: The Art of Preserving Animal and Vegetal Substances

At the end of the 18th century, Nicolas Appert (1749–1841), a French confectioner, developed an original method of preserving large amounts of foods for long periods. He found that the application of heat to food in sealed glass bottles preserved the food from deterioration. The “appertization” industry was thus born in 1795 at Ivry-sur-Seine, near Paris, where Appert began to elaborate heat-preserved food products (Barbier, 1994). In 1802, he relocated his activity to a bigger factory in Massy and produced preserved meat, vegetables and fruits.

At that time, foods were preserved with the addition of salt, alcohol, vinegar, sugar or fat or by drying and smoking. Unfortunately, all these processes deeply modified the intrinsic properties of food, and in particular their flavour. The preservation method proposed by Appert had the advantage of not altering the food. Gourmets and marine officers were the first to praise his invention. The former emphasized the “freshness” of preserved foods, allowing them to “enclose seasons in glass bottles”. The latter underlined the remarkable capacity of the process to preserve a variety of foods and the lack of spoilage of bottled perishable food products after durability studies performed aboard ships. The Navy was moreover particularly interested in this process, since it could prevent scurvy among ship crew members, which was attributed to the consumption of salted meats. In 1809, a committee of three members (Louis-Bernard Guyton-Morveau, Antoine Parmentier and Bernard-Felix Bouriat) of the Society supporting the National Industry published a report after testing ten animal and vegetable food products preserved for more than eight months. The committee reported that all foods were perfectly edible and expressed a positive opinion of Appert’s process.

The recognition of his work came in 1810, when Nicolas Appert chose to publish and disseminate his findings and received a 12,000 Franc grant from the Ministry of the Interior for his work. He published a book entitled *Le livre de tous les ménages ou l’art de conserver pendant plusieurs années toutes les substances animales et végétales* (The book for all households or the art of preserving animal and vegetable substances for many years) (Appert, 1810). He described the following successive steps in the process:

- enclose, in bottles or jars, the food to be preserved;
- cork the bottle carefully;
- submit the bottles to the action of boiling water for various lengths of time, depending on the food;
- remove the bottles after the prescribed time.

Food canning was empirically invented. The process was soon improved in England, where a method of sealing food into unbreakable cylindrical tin or wrought-iron canisters (“cans”) was developed. The efficiency of the thermal process was also improved, and the first pressure retort was built during the mid-19th century, allowing steam temperatures higher than 100 °C to be used. This provided the benefit of reduced thermal process times, which in turn improved the flavour, texture and nutritional value of the food.

Despite not understanding why the heat process prevented the food from going bad, Appert was convinced that his method depended on the action of heat inhibiting food spoilage. The French chemist Louis-Joseph Gay-Lussac (1778–1850) thought that oxygen present in bottles was modified by heating, allowing the preservation of foods. It was not until 50 years later that Louis Pasteur (1822–1895) provided the explanation for the effectiveness of canning when he demonstrated the role of microorganisms in food spoilage. In 1862, he performed experiments that proved that heat-treating beverages (milk, beer and wine), a process that became known as pasteurization, could stop them from spoiling.

The Botulinum Cook

Although the heating times prescribed by Appert were short, between one and two hours in boiling water (Appert, 1810), food spoilage and foodborne illnesses involving canned foods were not formally reported before the end of the 19th century. After 1895, the William Underwood Company in the USA, which experienced tin cans swelling, decided to launch studies to fix this problem. Many cases of canned food spoilage were studied by William Underwood and Samuel Prescott, who demonstrated that heat-resistant bacterial spores were the causative agents of spoilage and that the proper time–temperature combinations could prevent it (Wanucha, 2009). They were
the first to perform time–temperature studies and published time–temperature requirements of canned foods to control their spoilage.

More dramatically, at the same period, canned foods were also implicated in botulism outbreaks. Foodborne botulism is a very serious form of food poisoning, a flaccid paralysis with a high case-fatality rate caused by ingesting preformed Clostridium botulinum neurotoxin. The name “botulism” is derived from the Latin word “botulus” meaning sausage and came to be used in Europe in the 18th century to describe a disease associated with muscle paralysis, breathing difficulties without loss of cognition and a sensory system remaining intact, which was frequently linked to the consumption of blood sausage. At the end of the 18th century, cases of fatal poisoning were observed in Württemberg in southern Germany following the consumption of smoked blood-sausage (Erbguth and Naumann, 1999). In 1820 and 1822, the District Medical Officer Justinus Kerner published monographs detailing more than 200 cases of “sausage poisoning”, describing accurately the clinical presentation of foodborne illness and speculating on the mechanism of “the fat poison”. The causative agent, named Bacillus botulinus, was isolated in 1896 by Emile van Ermengem from inadequately cured ham in Belgium (Van Ermengem, 1979). He established that foodborne botulism was an intoxication, not an infection, and that the toxin was produced by a spore-forming anaerobic bacterium.

Spores of C. botulinum are ubiquitous in the environment. Spore germination and bacterial growth allowing the elaboration of toxin occur in anaerobic, low-salt (<10%), low-acid (pH > 4.6) environments at temperatures above 10 °C for classical proteolytic strains and 3 °C for nonproteolytic strains (Peck et al., 2011). The canning of foods is conducive to creating anaerobic conditions; hence, low-acid foods even slightly contaminated with C. botulinum spores receiving inadequate heat treatment, allowed to stand for a time and eaten undercooked (the toxin is heat-labile) may cause botulism.

In November 1913, an outbreak involved 12 young people at Stanford University who had consumed a string bean salad. Dickson (1918) was the first to observe that spores of C. botulinum could survive for two hours in boiling water and recommended that an educational campaign be instituted so that all who practised the home-canning of fruits and vegetables might be informed of the danger. The first outbreak of foodborne botulism recorded in the UK happened in August 1922 at Loch Maree, in Scotland. The consumption of sandwiches containing wild-duck paste preserved in a glass jar caused the death of eight persons (Leighton, 1923). There was little suspicion of commercial canning at that time. In the USA, from 1910 to 1919, there were 48 outbreaks attributed to home-processed food and 14 to commercially processed food. However, between August and November 1919, commercially canned ripe olives caused a total of 28 intoxications with 17 deaths.

Hence, in December 1919, the Canners League of California, the California Olive Association and the National Canners Association proposed and financed a detailed investigation by the University of California and the Stanford University. This project involved assessing the dangers of botulism in commercially prepared food, how it originates, and how it could best be eliminated. Karl Friedrich Meyer and his co-workers were entrusted with the investigation, and studies were carried out between 1919 and 1926 (Meyer, 1973).

Sterilization standards were scientifically established, derived from experiments exposing the spores of 109 different strains of C. botulinum to different heating temperatures and demonstrating that thermal destruction of the most resistant pathogens required a four-minute exposure at 120 °C and 330 minutes at 100 °C (Esty and Meyer, 1922). Sanitary standards of packing plants and inspection services regulating the processing of low-acid foods improved the safety of canned foods (Meyer, 1973). From this period, botulism did not disappear, but home-canned rather than commercial-canned foods became the leading cause of foodborne botulism (Hall, 1943; Sobel et al., 2004). In the USA, commercial-canned foods accounted for 32% of the 125 outbreaks of known source from 1910 to 1929 but for only 3.3% of the 305 outbreaks of known source reported during the period 1930–1959 (Sabin, 1980).

### Thermobacteriology: Modelling the Thermal Processing of Foods

Early time–temperature studies conducted at the beginning of the 20th century were carried out, giving rise to what was named “thermobacteriology” (Stumbo, 1949). Thermobacteriology is dedicated, on the one hand, to studying undesirable heat-resistant microorganisms potentially present in canned foods, and, on the other hand, to studying heat transfers in canned foods during thermal processing. Mathematical models were developed to describe the destruction of microorganisms during heat treatment. These models are very simple and allow the heat resistance of microorganisms to be characterized with only two parameters: $D$, the decimal reduction time (required heating time for a survival ratio of 10% of the microbial population) (Katzin et al., 1943), and $z$, the thermal death-time curve parameter (interval in temperature yielding a ten-fold change in $D$) (Bigelow, 1921).

Measurement of temperature during the heating and cooling of foods in hermetically sealed containers was performed and allowed models to be developed that described the transfer of heat to the food’s thermal centre for conduction or convection heating (Ball, 1923; Ball and Olson, 1957). Parameters characterizing bacterial resistance to heat were integrated with parameters describing heat transfer and heat intensity to estimate the amount of heating required to produce safe and “commercially sterile” food products (Stumbo et al., 1975). The lethality requirement depends on the acceptable statistical probability of observing surviving microorganisms. This includes both pathogenic and spoilage organisms that are capable of growth under the intended storage conditions. The classical acceptable survival probability of spores of C. botulinum is no greater than 1 viable spore in $10^{12}$ containers. Since the approximate maximum heat resistance of C. botulinum spores may be represented by a $D$-value of 0.21 min at 121.1 °C, the lethality requirement at 121.1 °C was rounded up to three minutes, known as the standard $F_{0.3}$ sterilization process (Stumbo et al., 1975).
An F₀₃ process is safe with respect to *C. botulinum* spores, but products may contain a small number of surviving spores of more heat-resistant spoilage microorganisms, jeopardizing the “commercial sterility” of canned foods. For spoilage, spoilage-forming mesophilic bacteria more heat resistant than *C. botulinum*, the acceptable probability of survival to ensure reasonably minor economic losses should be no greater than 1 viable spore per about 10⁴ containers (Stumbo *et al.*, 1975). Quality degradation calculations must therefore be performed in order to select the thermal process that results in the highest product quality retention. Indeed, while destruction of spoilage agents is achieved during the thermal process, quality degradation (nutrients, vitamins, colour, texture and flavour loss) also occurs. Therefore, from all the time–temperature combinations that comply with the minimum conditions necessary to free foods of microorganisms that might spoil the foods or endanger the health of consumers, those less deleterious to organoleptic and nutritive properties must be chosen. This optimization can be achieved by knowing the kinetics of quality degradation as a function of the time–temperature profiles (Holdsworth, 1985). Risk–benefit models can therefore be developed according to the time–temperature profile of the canning process and the intrinsic parameters of foods (pH, oxygen content) to manage the microbial spoilage risk versus the nutritional benefit of preserved foods (Rigaux *et al.*, 2012). These studies allow a compromise on process parameters to be identified, optimizing nutritional and organoleptic quality while keeping microbial risk at an acceptable level. These kinds of studies emphasize the never-ending need for greater precision in calculating and assessing heat processes for food preservation (Mafart *et al.*, 2010).

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