

Concerning the direct addition of nitrite to curing brine

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(originally Chapter 15 of [Bacon and the art of living](#))



Introduction

This originally appeared in [Bacon and the art of living](#) which is a study in the birth of the elements of bacon curing. Neither the chemical reactions, nor the different mechanical processes are simple. Everything about bacon is complex and beautiful. One of the most amazing stories within the grand story of bacon, is the story of sodium nitrite.

Pork is changed into bacon by the reaction of nitrite (NO_2^-). With salt, it is the curing agent. The meat industry uses nitrite in the form of an ionic compound, sodium nitrite. It is sold as Quick Cure or Insta' Cure, Prague Salt, Prague Powder or simply Pink Salt or Curing Salt. It is coloured pink to distinguish it from ordinary salt (sodium chloride). Every spice company sells it. It is the essential ingredient in the meat curing process.

Meat changes colour from the red fresh meat colour to an unappetising brown colour within days. (1) If one injects nitrite into the meat or rubs a mixture of salt and a small percentage of nitrite onto it, the meat will develop an appetizing reddish/ pinkish fresh meat colour (Hoagland, Ralph. 1914) and a characteristic cured taste. It will retain this colour for weeks and months if packed in the right conditions. (1) Nitrite provides an indispensable hurdle against a particularly nasty food pathogen, clostridium botulinum. It also endows the meat with a distinct cured taste.

During ages past, it has however not been nitrite that was added to meat to accomplish this, but its cousin, nitrate (NO_3^-). They may be cousins, but are very different in characteristics. *Nitrate* takes several weeks or even months to cure meat where *nitrite* accomplishes the same task in 12 hours. How the change happened from using nitrate or salpeter in meat curing to nitrite is an epic story.

Overview

This article tracks the migration of the meat industry from the use of saltpeter (potassium or sodium *nitrate*) as curing agent to sodium *nitrite*. It gives an overview of the scientific discoveries which started to reveal the mechanisms of meat curing. This understanding led to the realisation that a direct application of *nitrite* as the curing agent will be vastly superior to the use of saltpeter (*nitrate*).

This was a dramatic discovery since in the late 1800's and early 1900's, the world saw nitrite as a dangerous drug at best and a poison that polluted drinking water and cause death of cattle. Using this directly in food and meat curing was unthinkable.

Sodium nitrite was available in this time for application in the coal-tar dye and medical industries. Science and engineering have however not worked out its large scale production in a way that will make it a commercially viable proposition for direct use in meat curing from a price and availability perspective.

World War One provided the transition moments required to change everything. Germany invested heavily in nitrogen related technology for the war. The most organised scientific and engineering environment on the planet in the early 1900's focused its full attention on overcoming the manufacturing challenges in the service of the manufacturing of munitions. It also required this technology to overcome the challenge of being cut off, as a result of the war, from the natural sodium nitrate deposits in Chili that it required as fertilizer to drive its enormous agriculture sector during the war. At the same time, the use of saltpeter in meat curing was prohibited under the leadership of Walther Rathenau so that the valuable nitrate could be reserved for manufacturing of munitions.

This prohibition, I believe, was the initial spark that caused butchers to change to the use of sodium *nitrite*. At the same time, sodium nitrite was being produced in large volumes since it had, in its own right, application in the manufacturing of explosives. Health concerns and probably the need to have it reserved for munitions, led to a ban, similar to *nitrate*, on its use in meat curing. So, World War One solved the scientific challenges of large scale manufacturing of sodium *nitrite*, the engineering challenges of building production facilities and provided the impetus for the meat industry to change by banning the use of saltpeter in meat curing. The ban was lifted after the war.

Following the war, Germany had to find markets for its enormous war time chemical stock piles. One of the ways it "sold" sodium nitrite was as a meat curing agent based on its inherent benefits of curing consistency and the vastly shorter curing time required.

It was introduced to the world mainly through the Chicago based firm, Griffith Laboratories, who imported it as Prague Salt from Germany and later improved on it by fusing the sodium nitrite to sodium chloride and sold it as Prague Powder.

Early humans to Polenski (1891)

Early humans did not know they added nitrate to the meat. A mixture of salt and a small amount of saltpeter was used to cure meat in order to preserve it and to retain the fresh meat colour.

Salt peter is found naturally around the world in typically dry areas. Deposits exist in India, China, Mexico, the USA, and the Middle East. Despite its wide occurrence, the concentration of natural salt peter is low. (Whittaker, CW, 1932: 10)

Salt peter is also made by human effort. Europe, particularly Germany and France, Great Britain, India and the United States all acquired the technology to produce salt peter. (Van Cortlandt, P, 1776: 7, 8)

In South Africa, salt peter deposits are found in the Griquatown beds of the Transvaal geological system. It extends from just South of the Orange River Northwards to the Kalahari Desert and then Eastwards into the Old Transvaal from Zeerust to Polokwane. The nitrate deposits occur in the middle portions of these beds, in softer and more decomposed shale. These South African reserves have fortunately never been mined even though it was used on a small scale to make gunpowder for the old Boer government. (Whittaker, CW, 1932: 10)

Salt peter was at the heart of the arms race of the middle ages. It was used mainly in gunpowder, but as the world's population grew, it became indispensable as a fertilizer and for curing meat. (See *Bacon and the art of living*, chapters 2, 3 and 4)

The French chemist, Antoine Lavoisier worked out its chemical composition. It is an ionic compound consisting of the metal *potassium* and its power is *nitrate*. Potassium Nitrate. (*Mauskopf, MSH. 1995: 96*) Trade in Salt peter around the world was done through companies such as the Dutch East Indian Company (Dutch abbreviation, VOC) who traded it for its main use as an ingredient in gunpowder. It was by volume one of the largest commodities traded by the Dutch East Indian Company who set up the trading post in 1652 that became Cape Town.

Major developments shifted the balance of power away from India, China and home grown salt peter production to South America where huge deposits of sodium nitrate were discovered that would become the principal source of the world's nitrate for much of the 1800's.



A man walks down a dirt road in the Atacama Desert. Despite being one of the most inhospitable places on earth, the Atacama is still mined: in 2010 this made world-wide news, when the Copiapó mining accident led to the dramatic rescue of 33 trapped miners (AP Photo/Dario Lopez-Mills).

A popular legend tells the story of the discovery by two Indians in the Atacama Desert in the South of Peru. According to the legend, after a hard day's work, they camped in the Pampa and started a campfire to warm themselves. All of a sudden the ground started to burn and they ran away, thinking that they have seen the devil. They reported the event later to a priest in Camina who returned to the site. He had it analysed and found it to contain sodium nitrate (the same power as potassium nitrate, but linked to another common metal). The priest, according to the story, threw the rest of the soil in the courtyard of his house and saw the plants grew vigorously. He recommended the soil as an excellent tonic for the plant kingdom. (Wisniak, J, et al., 2001 :433)

So was discovered the enormous sodium nitrate deposits of the Atacama Desert. The fertilizer properties of the salt were known long before the 1600's. There are references to saltpeter and the nitrate ground in 1604. During the time of the Spanish Conquest, in the 1700's, miners working in the South of Peru realised that gunpowder could be manufactured from the material in the soil instead of potassium nitrate. (Wisniak, J, et al., 2001 :433)

A report published in 1803 by Juan Egana, Secretary of the Royal Court of Mines in Chile showed the Huasco region is "covered in a large part by a crust of niter salt, well crystallized, and several inches thick" (Wisniak, J, et al., 2001 :434)

The region was developed and by 1850 exports reached 24 000 tons/ year. In 1910 it was 2.4 million tons per year and by 1916, 3 million tons per year from 97 plants. (Wisniak, J, et al., 2001 :434)

By the beginning of the 1900's the country buying the largest quantity of the Chilean saltpeter was Germany (Wisniak, J, et al., 2001 :434) who used it aggressively in their agriculture sector as fertilizer.

There is a close correlation between sodium and potassium nitrate. It's difficult to distinguish between sodium and potassium nitrate just by tasting it. Scientists were able to distinguish between the two compounds from the mid 1600's and knew that sodium nitrate had a much greater ability to attract water (Whittaker, CW, 1932: 3). This made sodium nitrate a much better curing agent than potassium nitrate.

Nitrite was described in 1864 by the English Physiologist, B. W. Richardson. He outlined how to manufacture it and its chemical properties. (Wells, D. A., 1865: 233) Much earlier, in 1777 the prolific Swedish chemist Scheele, working in the laboratory of his pharmacy in the market town of Köping, made the first pure nitrite. (Scheele CW. 1777) He heated potassium nitrate at red heat for half an hour and obtained what he recognized as a new "salt." The two compounds (potassium nitrate and nitrite) were characterized by Péligré and the reaction established as $2\text{KNO}_3 \rightarrow 2\text{KNO}_2 + \text{O}_2$. (Péligré E. 1841: 2: 58–68) (Butler, A. R. and Feilisch, M.)

The technology existed in the 1800's to not only produce potassium nitrate (saltpeter) and nitrite, but to also test for these.

Remember that curing up till 1890 has been attributed to saltpeter (potassium nitrate) or Chilean saltpeter (sodium nitrate). In 1891 a German food scientist, Dr Ed Polenski, working for the German Department of Health made an observation that would change the world while studying curing brines. When he tested the curing brine made from saltpeter and salt, days after it was made, he found nitrite to be present. This was surprising since saltpeter is potassium or sodium nitrate, not nitrite.

Dr Ed speculated that the nitrate (NO_3^-) was changed into nitrite (NO_2^-) through bacterial action, a reduction step between nitrate and nitrite that was well understood by this time. He had a hunch that nitrite is responsible for curing of meat and not the nitrate directly, as was previously thought.

From Polenski (1891) to WWI (1914 to 1918)



Following Dr Ed's observations in 1891, considerable resources from around the world were dedicated to understand the chemistry of meat curing.

When World War One broke out, the concept of nitrite as curing agent (as opposed to nitrate) was firmly established.

Ralph Hoagland, Senior Biochemist, Biochemie Division, Bureau of Animal Industry, United States Department of Agriculture, published an article in 1914, *Coloring matter of raw and cooked salted meats*. In this article, he shows that nitrite as curing agent was a known and accepted fact by the outbreak of World War One (Hoagland, Ralph. 1914)

Readers who dont have an interest in the detailed description of the key discoveries may want to skip over the rest of this section altogether or glance over it generally. The goal of the section is to give the reader a sense of how firmly and universally the concept of nitrite as the curing agent was established by 1914. In the midst of the technical names and jargon, don't lose the sense of the universal interest. The 1700's, 1800's and beginning of the 1900's was a time when the average person was as interested in chemistry as we are today about communication and information technology.

The difference between nitrates and nitrites, for example, was taught in school curriculum. An article appeared in the Daily Dispatch in Brainerd, Minnesota in the 20's, that gives as an example of a diligent high school student, that he or she would know the difference. (The Brainerd Daily Dispatch (Brainerd, Minnesota). 17 January 1923. Page 3)

Following Dr. Polenski's observation, the German scientist, Notwang confirmed the presence of nitrite in curing brines in 1892, as observed by Dr Polenski, but attributed the reduction from nitrate to nitrite to the meat tissue itself. The link between nitrite and cured meat colour was finally established in 1899 by another German scientist, K. B. Lehmann in a simple but important experiment.

Karl Bernhard Lehmann (September 27, 1858 – January 30, 1940) was a German hygienist and bacteriologist born in Zurich.

In an experiment he boiled fresh meat with nitrite and a little bit of acid. A red colour resulted, similar to the red of cured meat. He repeated the experiment with nitrates and no such reddening occurred, thus establishing the link between nitrite and the formation of a stable red meat colour in meat. (Lee Lewis, W., 1925: 1243)

In the same year, another German hygienists, K. Kisskalt, confirmed Lehmann's observations but proved that the same red colour resulted if the meat was left in saltpeter (potassium nitrate) for several days before it was cooked. (Lee Lewis, W., 1925: 1243)

K. B. Lehmann made another important observation that must be noted when he found the colour to be soluble in alcohol and ether and to give a spectrum showing an absorption band just at the right of the D line, and a second band, often poorly defined, at the left of the E line. On standing, the color of the solution changed to brown and gave the spectrum of alkaline hematin, the colouring group (Hoagland, Ralph. 1914).

The brilliant British physiologist and philosopher, John Scott Haldane weighed in on the topic. He was born in 1860 in Edinburgh, Scotland. He was part of a lineage of important and influential scientists. (Lang, M. A. and Brubakk, A. O. 2009. The Haldane Effect)

J. S. Haldane contributed immensely to the application of science across many fields of life. This formidable scientist was for example responsible for developing decompression tables for deep sea diving used to this day. (Lang, M. A. and Brubakk, A. O. 2009. The Haldane Effect)

"Haldane was an observer and an experimentalist, who always pointed out that careful observation and experiments had to be the basis of any theoretical analysis. "Why think when you can experiment" and "Exhaust experiments and then think." (Lang, M. A. and Brubakk, A. O. 2009. The Haldane Effect)

An interesting anecdote is told about him from the time when he was studying medicine in Jena. He apparently carefully observed the amount of beer being drunk, noting that the students on the average drank about 20 pints per evening." (Lang, M. A. and Brubakk, A. O. 2009. The Haldane Effect)

Before we look at Haldane's contribution, let us re-cap what has been determined thus far.

Polenski and Notwang discovered that nitrite were present in a mix of saltpeter and salt, after a while, even though no nitrite were present when the brine was mixed.

Karl Bernhard Lehmann linked nitrite conclusively with the reddening effect of fresh meat that was boiled in a nitrite and water solution with some free acid. He also showed that this

does not happen if fresh meat is placed in saltpeter and water solution and boiled immediately. K. Kisskalt showed that the same reddening occurred if fresh meat is left in saltpeter for some time.

K. B. Lehmann managed to "isolate" the colour by dissolving it in ether and alcohol and analyze it spectroscopically.

What S. J. Haldele did was to apply the same rigor to cured meat and became the first person to demonstrate that the addition of nitrite to hemoglobin produce a nitric oxide (NO)-heme bond, called iron-nitrosyl-hemoglobin (HbFeII_{NO}). (Lang, M. A. and Brubakk, A. O. 2009: 119)

Nitrite is further reduced to nitric oxide (NO) by bacteria or enzymatic reactions and in the presence of muscle myoglobin forms iron-nitrosyl-myoglobin. It is nitrosylated myoglobin that gives cured meat, including bacon and hot dogs, their distinctive red color and protects the meat from oxidation and spoiling. (Lang, M. A. and Brubakk, A. O. 2009: 119)

This is how he did it. He concluded (1901) that its red colour is due to the presence of the nitricoxid hemochromogen resulting from the reduction of the coloring matter of the uncooked meat, or nitric-oxid hemoglobin (NO-hemoglobin). (Hoagland, Ralph. 1914)

Remember the observation made by K. B. Lehmann that the colour of fresh meat cooked in water with nitrites and free acid to give a spectrum showing an absorption band just at the right of the D line, and a second band, often poorly defined, at the left of the E line. (Hoagland, Ralph. 1914)

Haldene found the same colour to be present in cured meat. That it is soluble in water and giving a spectrum characteristic of NO-hemoglobin. The formation of the red color in uncooked salted meats is explained by the action of nitrites in the presence of a reducing agent and in the absence of oxygen upon hemoglobin, the normal coloring matter of fresh meats. (Hoagland, Ralph. 1914)

Ralp Hoagland (1908) studied the action of saltpeter upon the colour of meat and found that its value as an agent in the curing of meats depends upon the nitrate's reduction to nitrites and the nitrites to nitric oxid, with the consequent production of NO-hemoglobin. The red colour of salted meats is due to this compound. Hoagland conclusively shows that saltpeter, as such, has no value to preserve the fresh colour. (Hoagland, Ralph, 1914: 212)

The reason why the knowledge did not translate to a change in curing brines was very simple. The technology and infrastructure did not exist to produce enough nitrite commercially to replace saltpeter. This means that to produce nitrite was very expensive.

There were some attempts to capitalise on the knowledge gained. The German scientist, Glage (1909) wrote a pamphlet where he outlines the practical methods for obtaining the best results from the use of saltpeter in the curing of meats and in the manufacture of sausages. (Hoagland, Ralph, 1914: 212, 213)

Salt peter can only effect the colour of the meat if the nitrate in the salt peter is reduced to nitrite. Glage gives for the partial reduction of the salt peter to nitrites by heating the dry salt in a kettle before it is used. It is stated that this partially reduced salt peter is much more efficient in the production of color in the manufacture of sausage than is the untreated salt peter. (Hoagland, Ralph, 1914: 212, 213)

The fear of nitrites

The lack of a large scale production process for sodium nitrite and the engineering to build these plants were however not the only factors preventing the direct use of sodium nitrite in meat curing brines. As one review literature from the late 1800's and early 1900's, one realises that a major hurdle that stood between the use of sodium nitrites in meat curing was the mistrust by the general public and authorities of the use of nitrites in food. The matter relate to the high level of toxicity of nitrite, a matter that will be dealt with separately in [Bacon and the art of living](#).

The first recorded direct use of nitrite as a curing agent was in 1905 in the USA where it was used in secret. (Katina, J. 2009) The USDA finally approved its use as a food additive in 1906. (porkandhealth) This did not mean that the public would accept it.

Sodium Nitrite started to be used in this time as a bleach for flour in the milling industry. Several newspaper articles reveal public skepticism and the great lengths that the scientific community and industry had to go to in order to demonstrate its safety as a bleaching agent for flour. An article appeared in The Nebraska State Journal Lincoln, Nebraska on 29 June 1910 entitled, "*All for bleached flour. No harm can come from its consumption says experts*". The article deals with a federal court case about the matter and interestingly enough, it seems from newspaper articles that the government was opposing its use. Many other examples can be cited.

There is a 1914 reference in the London Times that shows the general view of nitrite as not just restricted to the USA. The article appeared on 9 June 1914 and a reference is made to sodium nitrite where it is described as "*a dangerous drug with a powerful action on the heart*." (The London Times. 1914. Page 118) The reference was to the use of nitrite for certain heart conditions.

It is interesting that sodium nitrite did not find an immediate application in the meat industry, even after it was allowed in 1906 in the USA.

In my view, this points to problems surrounding availability and price. If the issue was the public perception alone, this could have been overcome with a PR campaign by the meat industry as was successfully done by the milling industry.

On 13 Dec 1915 George F. Doran from Omaha, Nebraska, filed an application for a patent for a curing brine that contained nitrites. His application strengthens the evidence that it was not the knowledge of nitrite and its role in curing that was lacking, but availability and price. He states the objective of his patent application to "*produce in a convenient and more rapid manner a complete cure of packing house meats; to increase the efficiency of the meat-curing art; to produce a milder cure; and to produce a better product from a physiological standpoint*."

One of Doran's sources of nitrite is "sterilized waste pickling liquor which he [I have] discovered contains soluble nitrites produced by conversion of the potassium nitrate, sodium nitrate, or other nitrate of the pickling liquor when fresh, into nitrites. . ." "Waste pickling liquor is taken from the cured meats. Nitrites suitable for use in carrying out the present invention may be produced by bacterial action from nitrates and fresh pickling liquor by adding a small percentage of old used pickling liquor. The bacteria in old pickling liquor are reducing bacteria and change nitrates to nitrites." (Process for curing meats. US 1259376 A)

The use of old pickle has been described much earlier than Doran's patent. His usage of old pickle when he understood the reduction of nitrate to nitrite and nitrite's role in curing along with the fact that sodium nitrite was available can point to only one reason - price. It comes 10 years after sodium nitrite was first tested in curing brines for meat and shows that it has never become the curing agent of choice most probably due to limited availability and price. Much more about this later.

The post WWI era (1918 and beyond)



After WWI something changed. Saltpeter (potassium or sodium nitrate) has been substituted by the direct addition of nitrite to the curing brines.

The question is who pioneered this. Why and how did sodium nitrite production become so commonplace that it became available to bacon curing plants around the world?

Industry developments like this do not happen "by itself." Someone drives it in order for it to become general practice in an industry.

Chilean Saltpeter is a good case in point. Even though natural sodium nitrate deposits were discovered in the Atacama desert, it took a considerable effort on the side of the producers (mainly the Chilean Government) to work out the benefits of sodium nitrate and to market it to the world. It is, for example, famously reported that the first shipment to Britain was dumped in the sea before the ship docked on account that the cargo attracted customs duty and the ships owners could not see any commercial application for sodium nitrate. (2)

In the same way, the direct application of nitrite in curing brines must have been driven by someone.

The Griffith Laboratories, Inc.

The Chicago based company of Enoch Luther Griffith and his son, Carroll Griffith started to import a mixture of sodium nitrite and salt as a curing substitute for saltpeter from Germany in 1925. The product was called Prague Salt (Prague Powder, 1963: 3)

The Griffith Laboratories (3) played a key role in marketing the new curing brine in the USA. They took the concept of the Prague Salt (sodium nitrite) and in 1934 announced an improved curing brine, based on the simple use of sodium nitrite, where they fuse nitrite salt and sodium chloride in a particular ratio. They called it Prague Powder. Their South African agents, Crown Mills (4), brought the innovation to South Africa. (Prague Powder, 1963: 3, 4)

It is fair to assume that if Prague Salt was being sold to Griffith in the 1920's, the German producers must have sold it to other countries and companies around the world also.

The benefits of Prague Salt and later Prague Powder over Saltpeter is dramatic. Prague Salt (sodium nitrite) does not have the slightly bitter taste of saltpeter (Brown, 1946: 223). It allows for greater product consistency since the same percentage of nitrate was not always present in the saltpeter and the reduction of nitrate to nitrite takes longer or shorter under various conditions (Industrial and Engineering Chemistry, December 1925: 1243). The big benefit was however in the curing time required. Instead of weeks or even months that is required with saltpeter, curing could now be done in days or even hours with sodium nitrite. (The Food Packer, 1954: 64) From there, brand names like Quick Cure or Instacure.

This means that we have narrowed the time line for invention of Prague Salt (Sodium Nitrite) to between 1914, the beginning of the Great War and 1925 when Griffith imported it from Germany.

However, a document, published in the USA in 1925 shows that sodium nitrite as curing agent has been known well before 1925.

The document was prepared by the Chicago based organisation, *The Institute American Meat Packers* and published in December 1925. The Institute started as an alignment of the meat packing companies set up by Phil Armour, Gustavus Swift, Nelson Morris, Michael Cudahy, Jacob Dold and others with the University of Chicago.

A newspaper article about the Institute sets its goal, apart from educating meat industry professionals and new recruits, "*to find out how to reduce steers to beef and hogs to pork in the quickest, most economical and the most serviceable manner.*" (The Indiana Gazette. 28 March 1924).

The document is entitled, "*Use of Sodium Nitrite in Curing Meats*", and it is clear that the direct use of nitrites in curing brines has been practiced from earlier than 1925. (Industrial and Engineering Chemistry, December 1925: 1243)

The article begins "*The authorization of the use of sodium nitrite in curing meat by the Bureau of Animal Industry on October 19, 1925, through Amendment 4 to B. A. I. Order 211 (revised), gives increased interest to past and current work on the subject.*"

Sodium Nitrite curing brines would therefore have arrived in the USA, well before 1925.

It continues in the opening paragraph, "*It is now generally accepted that the saltpeter added in curing meat must first be reduced to nitrite, probably by bacteria, before becoming available as an agent in producing the desirable red color in the cured product. This reduction is the first step in the ultimate formation of nitrosohemoglobin, the color principle. The change of nitrate to nitrite is by no means complete and varies within considerable limits under operating conditions. Accordingly, the elimination of this step by the direct addition of smaller amounts of nitrite means the use of less agent and a more exact control.*"

Griffith describes the introduction and origin of Prague Salt and later, Prague Powder as follows in official company documents:

"The mid-twenties were significant to Griffith as it had been studying closely a German technique of quick-curing meats. Short on manpower and time, German meat processors began curing meats using Nitrite with salt instead of slow-acting saltpeter, potassium nitrate. This popular curing compound was known as "Prague Salt." (Griffith Laboratories Worldwide, Inc.)

The World War One link

The tantalizing bit of information from Griffith sets World War One as the background for the practical and large scale introduction of direct addition of nitrite into curing brines through sodium nitrite.

There has to be more to the reason for saltpeter being replaced by sodium nitrite as curing agent than the reasons given by Griffith. For starters, the meat industry has always been under pressure to work fast with less people due to pressure on profit margins. The need to cure meat quicker due to short manpower and time as a result of the war could not be the full story.

The World War One link from Griffith does not give all the answers, but it puts the introduction of sodium nitrite to meat curing between 1914 and 1918, at least 7 years before Griffith started to import Prague Salt.

A document from the University of Vienna would fill out the story. According to it, saltpeter was reserved for the war effort and was consequently no longer available as curing agent for meat during World War One. (University of Vienna). It was reserved for the manufacturing of explosives, and for example, the important industry of manufacturing nitrocellulose, used as base for the production of photographic film, to be employed in war photography. (Vaupel, E., 2014: 462) It gets even better. Not only did the prohibition on the use of saltpeter expand the information from Griffith as to why people started using sodium nitrite (macro movements in culture does not take place because of one reason only), but it provide a name to the prohibition.

In August 1914, the War Raw Materials Department (Kriegsrohstoffabteilung or KRA) was set up under the leadership of Walther Rathenau. It was Rathenau who was directly responsible for the prohibition on the use of saltpeter. (5) He therefore is the person in large part responsible creating the motivation for the meat industry in Germany to change from saltpeter to sodium nitrite as curing medium of choice for the German meat industry during World War One.

Walter Rathenau's actions may have motivated the change, but it was the developments in synthesizing ammonia, sodium nitrate and sodium nitrite which provided the price point for the compound to remain the curing agent of choice, even after the war and after the prohibition on the use of saltpeter was lifted.

Atmospheric Nitrogen

One of the most important scientific riddles to be solved in the late 1800's/ early 1900's was how to produce ammonia and its related chemicals from atmospheric nitrogen. Sir William Crookes delivered a famous speech on the *Wheat Problem* at the annual meeting of the *British Association for the advancement of Science* in 1898.

In his estimation, the wheat production following 1897 would seriously decline due to reduced crop yields, resulting in a wheat famine unless science can step in and provide an answer. He saw no possibility to increase the world's wheat yield under the prevailing agricultural conditions and with the increase in the world population, this posed a serious problem. He said, "*It is clear that we are taxed with a colossal problem that must tax the wits of the wisest.*" He predicted that the USA who produced 1/5th of the world's wheat, would become a net importer unless something change. He pointed to the obvious answer of manure, but observed that all available resources are being depleted fast.

Sir William saw a "gleam of light in the darkness" and that "gleam" was atmospheric nitrogen. (Otago Witness. 3 May 1900, Page 4)

It was the German Chemist, Fritz Harber who solved the problem, with the help of Robert Le Rossignol who developed and build the required high pressure device to accomplish this. (www.princeton.edu)

In 1909 they demonstrated that they could produce ammonia from air, drop by drop, at the rate of about a cup every two hours. "The process was purchased by the German chemical company BASF (a coal tar dye supplier), which assigned Carl Bosch the difficult task of scaling up Haber's tabletop machine to industrial-level production. Haber and Bosch were later awarded Nobel prizes, in 1918 and 1931 respectively, for their work in overcoming the

chemical and engineering problems posed by the use of large-scale, continuous-flow, high-pressure technology." (www.princeton.edu)

"Ammonia was first manufactured using the Haber process on an industrial scale in 1913 in BASF's Oppau plant in Germany." (www.princeton.edu)

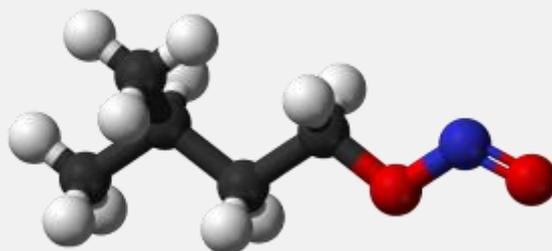
It was the vision and leadership of Walther Rathenau, the man responsible for restricting the use of saltpeter, that drove Germany to produce synthesized Chilean Saltpeter. He saw this as one of the most important tasks of his KRA. He said: "*I initiated the construction of large saltpeter factories, which will be built by private industries with the help of governmental subsidies and will take advantage of recent technological developments to make the import of saltpeter entirely unnecessary in just few months*". (Lesch, J. E., 2000: 1)

Fritz Harber was one of the experts appointed by Rathenau to evaluate a study on the local production of nitric acid.

During World War One production was shifted from fertilizer to explosives, particularly through the conversion of ammonia into a synthetic form of Chile saltpeter, which could then be changed into other substances for the production of gunpowder and high explosives (the Allies had access to large amounts of saltpeter from natural nitrate deposits in Chile that belonged almost totally to British industries; Germany had to produce its own). It has been suggested that without this process, Germany would not have fought in the war, or would have had to surrender years earlier." (www.princeton.edu)

So it happened that Germany became the leader in the world in synthesised sodium nitrate production and it effectively replaced its reliance on saltpeter from Chile with synthesised sodium nitrate, produced by BASF and other factories.

So, as a result of the First World War, sodium nitrite was produced at levels not seen previously in the world and in large factories that was build, using the latest processing techniques and technology from a scientific and an engineering perspective. Sodium nitrite, like sodium nitrate was being used in the production of explosives. Nitroglycerin is an example of an explosive used extensively by Germany in World War One that uses sodium nitrite in its production. (Wikipedia.org. Nitroglycerin and Amyl Nitrite)



Ball-and-stick model of Amyl nitrite used in the production of nitroglycerin. Amyl nitrite is produced from sodium nitrite. The diagram shows the amyl group attached to the nitrite functional group.

Sodium nitrite and the coal-tar dye industry

The importance of the manufacturing cost of nitrite and the matter surrounding availability can be seen in the fact that sodium nitrite has been around since well before the war. Despite the fact that it was known that nitrite is the curing agent and not nitrate, and despite the fact that sodium nitrite has been tested in meat curing agents, probably well before the clandestine 1905 test in the USA, it did not replace saltpeter as the curing agent of choice. My hunch is that it did not enter the meat industry as a result of cost.

The technology that ultimately is responsible for synthesising Chilean Saltpeter and made low cost sodium nitrite possible was being incubated in the coal-tar dye and textiles industry and in the medical field. The lucrative textiles and dye industry was the primary reason for German institutions of education, both in science and engineering to link with industry, resulting in a strong, well organised skills driven German economy. For example, "Bayer had close ties with the University of Göttingen, AGFA was linked to Hofmann at Berlin, and Hoechst and BASF worked with Adolph Baeyer who taught chemists in Berlin, Strasbourg, and Munich." (Baptista, R. J.. 2012: 6)

"In the late 1870s, this knowledge allowed the firms to develop the azo class of dyes, discovered by German chemist Peter Griess, working at an English brewery, in 1858. Aromatic amines react with *nitrous acid* to form a diazo compound, which can react, or couple, with other aromatic compounds." (Baptista, R. J.. 2012: 6)

Nitrous acid (HONO) is to nitrite (NO₂⁻) what nitric acid (HNO₃) is to nitrate (NO₃⁻).

According to K. H. Saunders, a chemist at Imperial Chemical Industries, Ltd., Martius was the chemist to whom the introduction of sodium nitrite as the source of *nitrous acid* was due. (Saunders, K. H., 1936: 26)

The economic imperative

The simple fact is that ammonia can be synthesized through the direct synthesis ammonia method at prices below what can be offered through Chilean Saltpeter. (Ernst, FA. 1928: 92 and 100) Sodium Nitrite can be supplied at prices below Chilean saltpeter and this made sodium nitrite the most effective curing agent at the lowest price since World War One.

As an example of the cost differences, the price of Nitric Acid (HNO₃) from direct synthesis in 1928 was \$23.60 per ton HNO₃ plus the cost of 606 lb. of NH₃ by-product and from Chilean Nitrate at \$32.00 per ton of HNO₃, plus the cost of 2840 N NO₃ by-product. (Ernst, FA. 1928: 112)

The advantage of scale and technology

By 1927, Germany was still by far the worlds largest direct syntheses ammonia producer. Production figures of the year 1926/ 1927 exceeded Chilean saltpeter exports even if compared with the highest levels of exports that Chilean saltpeter ever had in 1917. A total of 593 000 tons of nitrogen was fixed around the world in 1926/27. Of this figure, Germany produced 440 000 tons or 74%. The closest competitor was England through the Synthetic Ammonia and Nitrates Ltd. with a total capacity of 53 000 tons of nitrogen per year. (Ernst, FA. 1928: 119, 120)

In the USA 7 direct synthesis plants were in operation with a combined capacity of 28 500 tons of nitrogen per year. (Ernst, FA. 1928: 120)

Supporting evidence from the USA

The thesis that before the war, the production of sodium nitrite was not advanced enough for its application in the meat industry (resulting in high prices and low availability) is confirmed when we consider the situation in the USA.

The first US plant for the fixation of atmospheric nitrogen was build in 1917 by the American Nitrogen Products Company at Le Grande, Washington. It could produce about one ton of nitrogen per day. In 1927 it was destroyed by a fire and was never rebuild. (Ernst, FA, 1928: 14)

An article in the Cincinnati Enquirer of 27 September 1923 reports that as a result of cheap German imports of sodium nitrite following the war, the American Nitrogen Products Company was forced to close its doors four years before the factory burned down. The imports referred to, was as a result of Germany selling their enormous stockpiles of sodium nitrite at "below market prices" and not directly linked to a lower production price in Germany, even though this was probably the case in any event. (The Cincinnati Enquirer (Cincinnati, Ohio), 27 September 1923. Page 14.)

The Vienna University document indicate that the fast curing of sodium nitrite was recognised and the ban was lifted when the war ended. It was this fact that Griffith picks up on in their literature.

This is how it happened that sodium nitrite replaced saltpeter as curing salt.

Conclusion

The ban on the use of saltpeter for non military uses by Walther Rathenau is the likely spark that caused butchers to look at alternative curing systems. A known alternative was sodium nitrite. Despite a similar ban on the use of nitrite, later imposed for concerns over the safety of nitrite in meat and because sodium nitrite was also used to produce explosives, it was available in such large quantities around Germany that it was possible to defy the ban.

The likely consequence of the developments surrounding the production of atmospheric nitrogen is that sodium nitrite was being produced at prices that was previously not possible. These prices, combined with the volume of sodium nitrite now available made it a viable proposition to replace saltpeter in meat curing and to remain the curing brine of choice, following the war.

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Notes

(1) "The red color of fresh lean meat, such as beef, pork, and mutton, is due to the presence of oxyhemoglobin, a part of which is one of the constituents of the blood remaining in the tissues, while the remainder is a normal constituent of the muscles. When fresh meat is cooked or is cured by sodium chloride, the red color changes to brown, owing to the breaking down of the oxyhemoglobin into the two constituents, hematin, the coloring group, and the protein, globin.

On the other hand, when fresh meat is cured by means of a mixture of sodium chloride and a small proportion of potassium nitrate, or saltpeter, either as a dry mixture or in the form of a pickle, the red color of the fresh meat is not destroyed during the curing process, the finished product having practically the same color as the fresh meat. Neither is the red color destroyed on cooking, but rather is intensified." (Hoagland, Ralph. 1914)

(2) The first export of salitre (sodium nitrate) was authorised by the Chilean government in March 1830 and went to the USA, France, and to Liverpool. It is the latter shipment which failed and was thrown overboard. Different sources give different reasons for the action. One, that price was not attractive, another, that the excise duties were too high, and a third that the Port captain did not allow the boat to come in because it was carrying a dangerous load. A few farmers in Glasgow received a few bags. They used it as fertilizer and reported a three fold increase in crop yield. (Wisniak, J, et al. 2001: 437)

(3) Steve Hubbard, Vice President, Global Marketing and Innovation at Griffith Laboratories Worldwide, Inc. graciously provided me with much of the information from company documents.

(4) Crown Mills was bought out by Bidvest and became Crown National.

(5) The first War Raw Materials Department (KRA) in Germany was created (KRA) in mid-August 1914, as suggested by Walther Rathenau. (Vaupel, E. 2014: 462) Walter was the son of the founder of AEG and "one of the few German industrialists who realized that governmental direction of the nation's economic resources would be necessary for victory, Rathenau convinced the government of the need for a War Raw Materials Department in the War Ministry. As its head from August 1914 to the spring of 1915, he ensured the conservation and distribution of raw materials essential to the war effort. He thus played a crucial part in Germany's efforts to maintain its economic production in the face of the tightening British naval blockade."

References:

Baptista, R. J.. 2012. The Faded Rainbow: The Rise and Fall of the Western Dye Industry 1856-2000. From: http://www.colorantshistory.org/files/Faded_Rainbow_Article_April_21_2012.pdf

Brown, Howard Dexter et al. 1946. Frozen Foods: Processing and Handling

Butler, A. R. and Feelisch, M. New Drugs and Technologies. Therapeutic Uses of Inorganic Nitrite and Nitrate From the Past to the Future. From: <http://circ.ahajournals.org/content/117/16/2151.full>

Determination of nitrite in meat products. University of Vienna, Department of Analytical Chemistry, Food Analytical Internship for nutritionists.

Ernst, FA. 1928. Fixation of Atmospheric Nitrogen. D van Nostrand, Inc.

Griffith Laboratories Worldwide, Inc. official company documents.

Hoagland, Ralph. 1914. Coloring matter of raw and cooked salted meats. United States Department of Agriculture. National Agricultural Library. Digital Collections.

Hwei-Shen Lin. 1978. Effect of packaging conditions, nitrite concentration, sodium erythrobate concentration and length of storage on color and rancidity development of sliced bologna. Iowa State University Digital Repository @ Iowa State University

Katina, J. 2009. Nitrites and meat products. Czech Association of Meat Processors. <http://www.cszm.cz/clanek.asp?typ=5&id=1136>

Lang, M. A. and Brubakk, A. O. 2009. The Haldane Effect. The American Academy of Underwater Sciences 28th Symposium. Dauphin Island

Lee Lewis, W. December, 1925. Use of Sodium Nitrite in Curing Meat. Industrial and Engineering Chemistry.

Lesch, J. E.. 2000. The German Chemical Industry in the Twentieth Century. Kluwer Academic Publishers.

Mauskopf, MSH. 1995. Lavoisier and the improvement of gunpowder production/Lavoisier et l'amélioration de la production de poudre. *Revue d'histoire des sciences*

Nitrogen. University Science Books, ©2011

Otago Witness. 3 May 1900. Sir William Crookes and the wheat problem. Issue 2409, Page 4, from: <http://paperspast.natlib.govt.nz/>

Péligot E. 1841. Sur l'acide hypoazotique et sur l'acide azoteux. *Ann Chim Phys.*; 2: 58–68.

Prague Powder, Its uses in modern Curing and processing. 1963. The Griffith Laboratories, Inc.

Process for curing meats. US 1259376 A

Redondo, M. A.. 2011. Effect of Sodium Nitrite, Sodium Erythorbate and Organic Acid Salts on Germination and Outgrowth of *Clostridium perfringens* Spores in Ham during Abusive Cooling. University of Nebraska - Lincoln.

Salem, H. et al. 2006. Inhalation Toxicology, Second Edition. Taylor & Francis Group, LLC.

Saunders, K. H. The Aromatic Diazo-Compounds and their technical applications. Richard Clay and Company.

Scheele CW. 1777. Chemische Abhandlung von der Luft und dem Feuer. Upsala, Sweden: M. Swederus.

The Brainerd Daily Dispatch (Brainerd, Minnesota). 17 January 1923. Page 3.

The Food Packer. Vance Publishing Corporation. 1954

The Indiana Gazette, 28 March 1924

The Indiana Gazette. 28 March 1924.

The Nebraska State Journal Lincoln, Nebraska. Wednesday, June 29, 1910. All for bleached flour. No harm can come from its consumption says experts. Page 3.

The Times (London, Greater London). 8 June 1914. Adulteration. Examples of fraudulent manufacture. Page 118

The Times (London, Greater London). 1 May 1919. Government Property for by direction of the Disposal Board. Explosives and Chemicals. Prices were coming down in 1920, as reported in The Cincinnati Enquirer (Cincinnati, Ohio), 2 July 1920. Page 17.

Van Cortlandt, P, et al. 1776. Essays upon the making of salt-petre and gun-powder. Published by order of the Committee of Safety of the colony of New-York.

Vaupel, E. 2014. Die chemische Industrie im Ersten Weltkrieg Krieg der Chemiker. Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim

Wisniak, J, et al. The rise and fall of the salitre (sodium nitrate) industry. Indian Journal of Chemical Technology. Vol. 8, September 2001, pp 427 - 438.

Wells, D. A. 1865. The Annual of Scientific Discovery, Or, Year-book of Facts in Science and Art for 1865. Gould and Lincoln.

Whittaker, CW, et al. July 1932. A Review of the Patents and Literature on the Manufacture of Potassium Nitrate with notes on its occurrence and uses. United States Department of Agriculture. Miscellaneous Publications Number 192.

http://www.porkandhealth.org/filelibrary/PorkAndHealth/freebies_SodiumNitriteFactSheet.pdf

http://www.princeton.edu/~achaney/tmve/wiki100k/docs/Haber_process.html

<http://www.britannica.com/EBchecked/topic/491966/Walther-Rathenau>

en.wikipedia.org/wiki/Nitroglycerin

http://en.wikipedia.org/wiki/Amyl_nitrite

http://en.wikipedia.org/wiki/Amyl_nitrite

Images:

Picture 1: Smoker trolley with pork belly taken by Eben

Picture 2: Curing salt taken by Eben

Picture 3: Atacama Desert. Photograph by Dario Lopez-Mills/AP. Source: <http://www.theguardian.com/science/the-h-word/2014/jun/02/caliche-great-war-first-world-war-conflict-mineral>

Picture 4: World War One: <http://www.excaliburunit.org.uk/#/world-war-1/4580632440>

Picture 5: US troops returning from World War One. <http://www.ww1medals.net/WW1-US-Victory-medals.htm>

Picture 6: Amyl nitrite. http://en.wikipedia.org/wiki/Amyl_nitrite