

A REVIEW OF THE PRESENT KNOWLEDGE OF SODIUM NITRATE, TOGETHER WITH THE ORIGIN, PRODUCTION, AND DESTRUCTION OF NITRATES IN THE SOIL.¹

The importance of nitrates in technical processes, as well as in providing a quickly and certainly available plant food for admixture with chemical fertilizers, or for use alone, by the agriculturist, cannot well be overestimated. It is comparatively a few years since the vast stores of sodium nitrate in Chili have been sufficiently exploited to impress the world with their importance as a source of supply for the above demands, and I apprehend that the president of this society felt that it would not be time wasted when he invited me to direct the attention of the society to the origin, and to some of the uses of sodium nitrate, and also to some of the recent extensions of scientific knowledge in regard to the production of nitrate within the soil.

The rate at which the use of sodium nitrate is increasing in the United States, is shown by the following :

In 1897 the deliveries for January alone were 60,000 bags.

In 1898 " " " " " " " " 80,000 "

In 1899 " " " " " " " " 90,000 "

The yearly consumption in the United States for 1897, was 700,000 bags; for 1898, 975,000 bags. The total consumption of the world for 1897, was 8,050,000 bags; for 1898, 9,235,000 bags. A bag is approximately 300 pounds. The increased consumption in this country during the past year was 275,000 bags. These figures refer only to the Atlantic ports.

It speaks volumes for the influence of scientific men upon the development of practical agriculture in the world, when we remember that it is scarcely ten years since the agricultural experiment stations and scientific investigators began to vigorously direct public attention to this source of plant food. In fact, in this country, it has scarcely been so long, and it is only within the last two or three years that our experiment stations have been able to readily procure it.

There are two reasons for this rapid development :

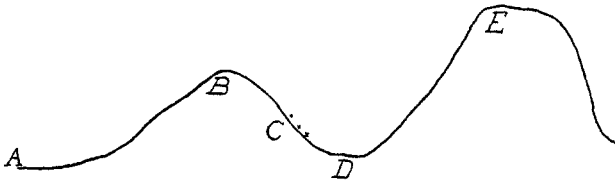
(1) The almost absolute certainty of securing satisfactory results when a scientific man or a farmer uses it for experimental or practical purposes.

(2) The wonderful influence it has had upon the development of the beet-sugar industry in Germany and other parts of the world.

¹Read before the New York Section of the American Chemical Society, February 10, 1899.

Its action upon vegetation is so certain and so uniform, and the demand of crops for additional supplies of it in the soil is so universal, that an experiment station can scarcely mistake in recommending the use of sodium nitrate, where the conditions affecting the production of bountiful crops are obscure. It is probably the most stimulating fertilizer in the market, and while the most satisfactory results can be obtained from it when in combination with ample supplies of available phosphoric acid and potash, which if not already found in the soil, should be applied to it in order to secure most bountiful harvests, yet as a special fertilizer a moderate application of nitrate alone, on most soils, proves highly remunerative.

At present, the entire supply of sodium nitrate comes from Chili, although it is found in some other parts of the world, but not in sufficient quantities to compete in the markets of the world. The portion of the west coast of Chili, where it is found, between latitudes $19^{\circ}12'$ south, and $25^{\circ}45'$ south, extends over a length of approximately 260 geographical miles. The principal deposits are found in the provinces of Tarapaca and Antofagasta, in Chili, and the center of trade is Iquique. It exists in a long, narrow strip, averaging about two and one-half miles in width, extending along the eastern slope of the Coast Range, at an average distance of perhaps fourteen miles from the ocean, but in a number of cases it is probably as much as forty miles from the coast. The region where it is found is a rainless desert, absolutely devoid of vegetation. The nitrate beds exist at a height of from 3,000 to 5,000 feet above sea-level, and extend down towards the valley of Tamagrue. The following rough sketch, not drawn to scale, will serve to illustrate the characteristic surface of the portion of Chili where the *caliche* is found. It will be seen that it lies between the Coast Range and the Cordillera.



A = Pacific Ocean; B = Coast Range of Mountains; C = Location of *Caliche* Beds;
D = Valley of Tamagrue; E = Cordillera.

I cannot undertake the discussion of all of the theories in regard to the origin of these beds, but suffice it to say that the most satisfactory explanation seems to be that they have resulted from the decay of enormous quantities of organic matter particularly seaweed which probably accumulated in a long, narrow strip of water, somewhat like Core Sound on the coast of North Carolina.

This accumulation, in the course of ages, was elevated. One of the evidences of this lies in the fact that the remains of seaweed are found in the nitrate deposits. The beds are 500 or 600 feet above the valley of Tamagruel, and extend down toward it, decreasing in value as they approach it, until they finally disappear upon reaching it. The beds exist under the following conditions, and skilled prospectors can generally locate the beds with considerable certainty by the surface indications :

The surface for a depth of approximately ten inches is covered with a layer of fine, loose sand; under the sand is found a layer of amorphous porphyry, feldspar, sodium chloride, and other mineral matter, cemented together by gypsum into a compact mass varying in thickness from six to ten feet. This is called *costra* or crust. Under this crust is found the *caliche*, or impure sodium nitrate, varying in thickness from a foot and a half up to about twelve feet. The *caliche* occurs in a great variety of colors, as yellowish white, orange, blue-gray, and dirt color. This deposit is a regular stratum, with all the appearances of a rock formation, firmly cemented together, and is displaced from its natural position, by blasting. The system of blasting is peculiar in this, that they drill a hole through the crust and through the *caliche*, down to the clay surface beneath, large enough to admit a boy, who is let down and excavates the clay under the *caliche*, so that the blast can be placed under the material to be broken up, the object being to thrust up as large a mass of *caliche* as possible. This is then broken up by the tools of the workmen into chunks the size of an orange, and the impurities as carefully removed by the process of selection, as possible. This crude material is then transported to the works where it is run through a crusher, and dissolved in hot water. The better quality of *caliche* contains from forty to fifty per cent. of sodium nitrate. The average quality from thirty to forty per cent. of sodium nitrate, and the poorest quality that is worked, from seventeen to thirty per cent. of sodium nitrate. The best quality of *caliche* runs about as follows :

	Per cent.	
Sodium nitrate.....	50	
Sodium chloride	26	
Sodium sulphate.....	6	
Magnesium sulphate.....	3	
Insoluble	14	
Sodium iodate	}	
Sodium nitrite		
Magnesium chloride		1
Potassium chloride		
Magnesium nitrate		
	100	

Under the present depressed condition of the industry, it is not profitable to mine *caliche* with less than about thirty per

cent. of nitrate. The refining of *caliche* and the extraction of the sodium nitrate, depends upon the fact that sodium nitrate is very much more soluble in hot water than in cold water, while the solubility of salt in water, is little increased with increased temperature. However, the solubility of the nitrate in water at 20° C. is affected by a solution of salt, and while 100 parts of water, at 20° C., should dissolve 88 parts of sodium nitrate, when it contains 25 parts of sodium chloride in solution, it will dissolve only 52.8 parts of sodium nitrate.

The time at my command does not permit me to go into the details of the three systems in use in carrying out the solution, crystallization, and drying of the sodium nitrate. The crystallized sodium nitrate is removed from the mother-liquor and allowed to drain some time, after which it is put into sacks, where it drains still further, for a certain length of time, and the granulated appearance of the sacks as they come into our market is due to the crystallization of this drainage material upon the outside of the sacks.

The mother-liquor, from which the first crop of crystals is taken, can be used for dissolving a fresh supply of *caliche*, but it is not practicable to use it more than twice or three times. This mother-liquor which contains the impurities of sodium nitrate is worked over for the iodine contained in it. In fact, all of the iodine in the market at present, is produced as a by-product in the refining process of sodium nitrate, and could be thrown upon the market in such large quantities, that the price of iodine would be reduced to a very much lower figure, were it not for the fact that it is under the control of a combination, which regulates the output.

There is another product that might be secured, if some one could devise a profitable and sure method of manipulating it, and that is the sodium perchlorate. In some of the mines an appreciable percentage of sodium perchlorate is found mixed with the nitrate, and the chemist who can devise some cheap and effective means of extracting the perchlorate, will undoubtedly find it a very profitable discovery, as its presence is highly objectionable when found in the sodium nitrate, whether it be used as a fertilizer or for technical purposes.

There are two grades of sodium nitrate in the market: One grade, containing not less than ninety-six per cent. of sodium nitrate, or over sixteen per cent. of nitrogen, is imported for technical purposes,—manufacture of chemicals, and chemical industries. Then there is the second grade, called ninety-five per cent. nitrate, which contains not less than fifteen per cent. of nitrogen, imported more especially for fertilizer purposes. The sodium nitrate as it comes into this country is of very uniform composition and can generally be relied upon to analyze very

close to the figures given. It generally contains from one per cent. to two per cent. sodium chloride, which is largely due to the difficulty of crystallizing out the sodium nitrate on a large scale without also securing a little of its impurities. Where it is desired to have purer nitrate than is produced at the works, it should be recrystallized.

Sodium nitrate is used

- (1) As a special fertilizer.
- (2) In compounding complete fertilizers.
- (3) In the manufacture of sulphuric acid.
- (4) In the manufacture of nitric acid.
- (5) In the manufacture of nitrate of potash.
- (6) In the manufacture of arseniate of soda.
- (7) In the manufacture of fireworks.
- (8) In the manufacture of fusing mixtures.
- (9) In the purification of caustic soda.
- (10) In the manufacture of steel.
- (11) In the manufacture of glass.
- (12) In the manufacture of minium.
- (13) In the curing of meat.
- (14) For making chlorine in the manufacture of bleaching-powders.

From the above list of the uses to which sodium nitrate is put, it will be seen at once that it plays a very important part in the industrial development of the country, and the question naturally comes up, "How long will the available supply last?" As I showed above, the consumption amounts to approximately 1,000,000 tons a year. There are at present exploited in Chili, beds of *caliche* estimated by different geologists to contain from 63,000,000 to 120,000,000 of tons of nitrate, and it seems that only a very small proportion of the territory where nitrate is likely to be found has yet been exploited, so that we need have no fear of the supply giving out during the next generation.

I have devoted considerable time to a review of facts, some of which are doubtless familiar to all of you, but all of which are probably not familiar to all chemists and are not readily accessible to many. Its use as a fertilizer, as it becomes known, will undoubtedly extend very widely. At present prices, it is perhaps the cheapest source of nitrogen in our markets.

But I must now turn my attention to another phase of the question, which is forced upon us by the rôle that sodium nitrate plays in agriculture. Agricultural chemists in particular have been laboring for years upon the problem of furnishing some cheap, natural means of producing nitrate rapidly, and in season for agricultural uses. It has been demonstrated beyond the shadow of a doubt that the majority of agricultural crops

appropriate their nitrogen in the form of nitrates, a few being able to utilize it to a limited extent in the form of ammonia or humate of ammonia, and still others being able to secure their nitrogen supply by the action of micro-organisms which develop tubercles upon their roots, and enable them in this way to appropriate supplies of nitrogen which may be secured from the air or from nitrogenous compounds decomposing in the soil. There has sprung up, in connection with the study of these problems, almost a new branch of chemistry; that is, the study of the chemical reactions evolved by microscopic life.

Stutzer and Hartleb have shown that all cultivated plants, with the probable exception of the leguminosæ, appropriate their food in the form of nitrates, which are derived either from the fertilizers applied to the land, or from the nitrogenous substances in the soil which are converted into nitrates by the action of nitrifying bacteria. It has not yet been shown exactly in what form the nitrogen, appropriated by the leguminosæ through the bacteria existing in the tubercles upon their roots, is finally appropriated by the plant. It is, however, certain that the tubercles upon plants of this class are not able to appropriate the nitrogen from nitrates more freely, if indeed as freely, as they can from the free nitrogen of the air or soil. These tubercles upon the roots are the laboratories of the plant, apparently for the purpose of transforming the nitrogen of the air into suitable plant food for that class of plants. It is also quite well established by numerous investigators that the micro-organisms found in these tubercles have the power of producing within the soil where the plants grow, a capacity for storing up nitrogen, either in the roots of the plants themselves, or in the soil immediately surrounding them, in a form which can be appropriated as plant food by succeeding crops. Thus, crops of clover or peas, beans, vetches, serradella, lupines, and similar plants, apparently cause an accumulation of available nitrogen in the soil where they grow. The amount of this nitrogen accumulated from year to year is not large, but is sufficient to produce a perceptible effect upon the succeeding crop, and if it were possible by this means to continue indefinitely the growth of crops of this character upon the same land, it might be possible to fertilize the land by means of clover, peas, or other green manures of this character up to the point where maximum crops could be secured without the addition of fertilizers from other sources. These crops (especially clover) are looked upon with much favor in sections of our country where extensive farming, in contradistinction to intensive farming, is largely pursued. Not only do these crops, whether in the form of green manures plowed under, or simply as nitrogen storers, accumulate nitrogen within limited margins, but they also improve the physical condition of the soil, so as to

enable the succeeding crops to more readily secure plant food existing in the soils. The importance of these nitrogen storers to the development of agriculture cannot therefore be overlooked, but as it is not evident that they derive their nitrogen from, or convert it into, any form of nitrate before the plant appropriates it, I will not enter further into the discussion of their use.

Hellriegel and Wilfarth found that certain soils would not produce satisfactory crops of these nitrogen gatherers unless they had been derived from fields where these crops had been grown, even when provided with abundant supplies of nitrogen in the form of organic compounds, or of nitrate. These pots, however, could be made to produce luxuriant growths of these nitrogen gatherers, if watered with the extract of the soil where the plants had grown. If the plants were watered with the sterilized solution of the soil, no growth was produced. The same pots, however, would produce a growth when watered with the unsterilized solution of the soil.

Nobbe went one step further, and reasoned that these unfruitful soils could be made fruitful if inoculated with the micro-organisms existing in, and probably producing, the tubercles. His experimental work was carried out with a view of determining the truth or falsity of this hypothesis. Operating upon sterilized soils containing ample supplies of available plant food, he found that his nitrogen gatherers would not grow beyond the point where they derived their supplies of nitrogen from the seed in sterilized soil, and that no tubercles were developed upon the roots of these plants. If, however, the soil was treated with a solution of pure culture of the bacteria existing in the tubercles, it immediately became fruitful and developed plants with abundant root tubercles. He found further that while the pure cultures indicated that the micro-organisms existing in the tubercles of the various nitrogen growers appeared to be the same under the microscope, yet they were not capable, except in a minor degree, of producing tubercles upon other members of the leguminosæ. For example :

The pure culture derived from the tubercles of the pea would produce tubercles upon the different varieties of peas, but might have little or no effect upon beans, or upon clover. So that he arrived at the conclusion that each plant had its particular class of micro-organisms capable of producing ample supplies of tubercles upon the roots of its own or closely related species, but incapable of producing tubercles upon plants remotely related to it. In connection with carrying out this idea in its practical applications, he set to work to prepare pure cultures of the organisms characteristic of the above plants, and a company has been organized in Germany for the preparation of these pure cultures upon a commercial scale. The medium employed is agar-

gelatine. This is inoculated with the germs derived from the tubercles of the clover, the lupine, the pea, etc., as may be required, and is furnished under the name of *Nitragin* for the inoculation of soils with proper germs for the production of the desired crop.

The inoculation of the soil with these germs is effected in two ways :

(1) By moistening the seed with a solution of the inoculated agar-gelatine.

(2) By moistening dust or fine earth with a solution of inoculated agar-gelatine, and working it into the soil.

Probably the best results have been obtained from the latter process.

It has been found, experimentally, that soils which would not produce particular crops of these nitrogen gatherers before inoculation, could, in some cases, be made to produce fair crops by the inoculation. As a scientific curiosity it is of great value. In practice, however, it has failed to yield satisfactory results, and the time does not yet seem to have arrived when this system can be economically applied by the farmer. It should be remembered, also, that this principle applies only to the nitrogen gatherers, or plants deriving their nitrogen supply through tubercles. It costs about two dollars an acre to properly inoculate a field with the organisms necessary to produce any particular kind of leguminous plant. The uncertainty of the inoculation proving successful is so great, that Prof. Paul Wagner, Director of the Darmstadt Experiment Station, Germany, recommends the farmers of that country not to attempt it.¹

Caron-Ellenbach has gone one step farther than the above, and has attempted to increase the capacity of the soil for directly absorbing nitrogen from the air. He has isolated and produced the pure culture of an organism which he has christened *Bacillus-Ellenbachensis* α which he finds possesses, in high degree, the power of causing the soil to absorb atmospheric nitrogen and transform it into available plant food. His claim is that soil inoculated with this bacterium increases its capacity for yielding up nitrogen in an available form for cereals and other crops, and that it absorbs large quantities of nitrogen from the air, and produces ample supplies for the use of the plants without resorting to expensive commercial fertilizers. The pure culture of this bacterium is also manufactured on a commercial scale by a firm at Elberfeld, Germany, and is sold under the name of *Alinit*. This preparation, like *Nitragin*, has in practice been found to be a scientific curiosity, but while *Nitragin* has considerable experimental evidence to show that it frequently may

¹ The most successful work done in this country upon this subject is by J. F. Dugar, Ala. Exper. Station Bull. No. 87.

increase the production of the leguminosæ, there is not, so far as I have been able to discover, any appreciable amount of scientific evidence to substantiate the claims set up for *Alinit*. In fact the *Bacillus-Ellenbachensis* α seems to be such a delicate creature, that the probability of its ever attaining any prominence in increasing the world's production of cereals, is relegated to the distant future.

While both of these discoveries are of great scientific interest, neither of them, I think, can be considered as anything more than demonstrating the fact that scientific men are working along very close to the lines where scientific discoveries of great practical value might be made.

Could the result sought to be attained above, be successfully and economically accomplished, the perplexing nitrogen problem would be solved for the farmers, but as they have not accomplished the results, it is necessary for scientific men to look further. The most promising field at present seems to me to be the study of the soil conditions which promote the rapid formation of nitrates, because that is the objective point to which we must direct all of our energies before we can expect to have any fertilizer, or any source of nitrogen supply utilized by the plant. We may have present in the soil, an abundant supply of nitrogen, and yet the plant may starve to death for nitrogen, because it exists in an unavailable form and cannot be converted into available form in time for the plant to utilize it.

The meteorological conditions most favorable to the production of nitrates are quite well known. But these we cannot control. It is demonstrated that there is a continual change going on in the supplies of nitrates present in the soil. They are carried down by the heavy rains, and they rise to the surface as the soil dries, so that there is a continuous movement of them in the soil. If the supply is ample, it is shown by a dark-green, luxuriant growth of vegetation. If it is inadequate, it is indicated by a stunted growth, and a yellowish-green color. The experimenter, therefore, is always in a position to determine, approximately, whether his plants are securing a sufficient supply of nitrates.

Until comparatively recently, the methods of analysis for detecting nitrates were not sufficiently delicate to throw full light upon the problem. Since, however, it has been discovered that the sulphate of diphenylamine is a sufficiently delicate test for nitrate to indicate one part in 100,000,000, it has been possible to shed much light upon the movements of nitrates, and the existence of nitrates in agricultural plants. Serno has found nitrates in almost all families of plants. The largest quantities occur in Malvaceæ, Cruciferae, Papervaceæ, Convolvulaceæ, Labiatae, Compositae, and Urticaceæ. In many plants it occurs

only in the roots, and more especially only in the newly formed, absorbing roots. He finds that it is stored in the roots during the winter in some; in others it is found only in the spring. In annuals the nitrates occur abundantly in all parts.

Deherain has found that wheat will store as much as one per cent. of nitrates in the roots of the plant during the winter time, and that if the dry roots be dipped in a solution of the sulphate of diphenylamine, they take on a deep blue color, indicating the presence of a very large percentage of nitrates retained in the roots preparatory for use when growth starts in the spring. Damussy has found that these nitrates are not washed out from the roots by cold water, although they are readily extracted by warm water, or when the roots are subjected for some time to an atmosphere of chloroform and then washed with cold water. This, he thinks, indicates that the nitrates are held in the roots in some very unstable compound, perhaps with the protoplasm, and resume their normal condition whenever the protoplasm is modified by an elevated temperature, or by chloroform.

Serno is of the opinion that nitrates stored in the roots of plants during the winter, which, as growth begins in the spring, may be traced into the stems of the plants as they move up to the leaves and finally lose their identity in the leaves, are converted by the changes taking place in the growing plant, into some form of amides, especially, perhaps, asparagine. Our methods of analysis, however, are not sufficiently perfected to trace these compounds exactly to the point where this change takes place. They can be followed up the plant in the spring, quite distinctly in the roots, less distinctly in the stem, and they gradually disappear as they rise. This principle applies to a very large number of agricultural plants, and the power of these plants to store up nitrates in their roots is of great advantage in keeping a supply of available nitrogenous plant food within reach, which would otherwise have been washed out of the soil by the fall and winter rains. It is familiar to all of us that the nitrates form in greatest quantities during the moist, warm summer months, and that they exist in the soil in largest proportions in the latter part of the summer. This storing capacity of plants therefore is of great importance.

S. Winogradsky has devoted a large amount of time and attention to the study of the nitrifying organisms which convert ammonia salts into nitrates. He began by operating upon the soils around Zurich, and has extended his investigation to cover samples of soil taken from many countries of the world and from all climates. He has succeeded in isolating and preparing the pure culture of a group of organisms, called by him 'nitromonas,' which he is disposed to consider rather as a group of bacteria than as a single species whose special function is the

oxidation of ammonia. He had already isolated bacteria whose special function was the oxidation of sulphur compounds and also the oxidation of iron compounds, which he named respectively 'sulfo-bacteria' and 'ferro-bacteria.' He therefore named these producing nitrate, 'nitro-bacteria.' He found that the nitromonas secured from different parts of the world possessed varying degrees of intensity of action. In the pure cultures, those from Europe acted slowly, and after a few generations of pure cultures, lost the power of oxidizing ammonia salts, while those secured from the soils of South America and Africa attacked the ammonia salts with great energy and seemed to acquire greater activity with successive generations. He has done an immense amount of work in the study of these bacteria, and has shed much light upon the peculiarities of their actions.

He also found that the nitromonas developed normally either in the light or darkness, and that they can assimilate the carbon from carbon dioxide in entire darkness. They are able, in entire darkness, to appropriate this carbon from carbonates or from carbon dioxide, and cause it to combine with the nitrogen to form organic matter, without the aid of the sun's rays. He believes that some sort of an amido compound is produced at the expense of the carbon dioxide and the ammonia. These chemical changes developed by the nitromonas, differ materially from those which occur with chlorophyl. In the action of chlorophyl, carbon dioxide is decomposed by the sun's rays, the oxygen liberated, and the carbon unites with the hydrogen and oxygen to form carbohydrates, but the investigations of Winogradsky indicate that the nitro-bacteria, instead of decomposing the carbon dioxide and setting oxygen free, effects its union with ammonia and makes use of the oxygen of the air to oxidize the nitrogen to nitrous and nitric acids, the energy for this change being supplied to them from the oxidation which they bring about. At this point there is room for still further investigation which, I believe, Winogradsky is engaged upon.

The conditions favorable to the oxidation of nitrogen compounds to nitrous and nitric acids, by the respective nitrifying organisms whose special function is to bring about these changes, have been studied extensively by Warrington, Schlösing, Winogradsky, and others, and the conditions favorable to the production of nitrates in the soil are quite thoroughly understood, and if we were able to control the meteorological conditions, it would perhaps not be a difficult matter to develop in the soil a very large quantity of nitrates suitable for plant food. As we are unable, however, to control the meteorological conditions, the best that can be done is to see that the soil is properly drained, properly cultivated, and supplied with a sufficient quantity of

lime or other alkali, to prevent the acidity from interfering with the regular processes of nitrification.

Even with this, however, it has been shown by E. Breal that there may be an extensive destruction of nitrates by the action of an antagonistic bacterium or ferment, which he finds developing extensively, especially upon straw and other vegetable refuse. This ferment has the power of attacking the nitrates and liberating the nitrogen as free nitrogen. It has long since been shown that putrescent fermentation reduces nitrates to the lower oxides and finally to ammonia. This ferment, however, acts differently in that it does not reduce the nitrates to lower oxides, but sets the nitrogen free. In one case, one-third of the nitric acid under experimentation disappeared: in another, sixty-seven per cent. of the nitric nitrogen disappeared. The rapidity of the decomposition has been measured and the products of decomposition analyzed. He has shown that when the soil containing nitrates is drying, and the nitrates rising, if covered with wet straw or other vegetable refuse and allowed to dry out slowly, nitrates are not found either in the straw or surface soil. This condition, in his judgment, accounts for the failure to find nitrates in meadows, forests, or other lands strown with large amounts of vegetable refuse, a fact which was also noticed by Boussingault. It also accounts, probably, for a large amount of the loss of nitrogen which occurs when green manures are used. It is a notorious fact that a large percentage of the nitrogen stored in a crop used as a green manure seems to escape, and the discovery of this ferment by Breal probably accounts for it. We are therefore confronted by these difficulties in the production of nitrates in the soil:

(1) The reduction of nitrates by putrefactive fermentation.

(2) By the action of Breal's bacterium.

So that it seems not to be possible to produce in a soil under normal conditions, more than a very small percentage of nitrate, and rarely enough to answer the maximum requirements of a large crop.

Time will not permit me to notice the work of all of the investigators who have contributed to extend our knowledge of the activity and peculiarities of the bacteria which perform so much work for the benefit of agriculture. There is one more investigation which I wish to notice, and I am through. It is well known that there is great diversity in what is known as the availability of nitrogen in its various forms when used in compounding fertilizers, or when used as a direct fertilizer upon the land. This variation in availability is dependent upon the readiness with which the nitrogen compound, whether it be ammonia salts or vegetable or animal refuse, is converted into nitrates.

Recently, S. W. Johnson, E. H. Jenkins, and W. E. Britton, of the Connecticut Experiment Station, undertook an investigation to determine the availability of a number of the chief sources of nitrogen, used for compounding our commercial fertilizers. They used for this purpose, oats, Hungarian grass, and rye. The soil upon which the experiments were conducted was quite thoroughly exhausted by previous crops, and ordinary precautions to prevent errors creeping in were observed. They determined the percentage of available nitrogen in different sources of nitrogen, as shown by the plants indicated in pot experiments, as follows :

	Per cent.
Sodium nitrate	100.0
Dried blood	73.3
Dried fish	93.9
Ground bones	16.7
Tankage	49.4
Horn and hoof powder.....	63.3
Linseed meal	68.9
Cottonseed meal.....	64.8
Castor pumice	64.6

It will be noticed in this experiment, as is now generally the case, that sodium nitrate is taken as the standard of availability.

There is one other possible source of nitrate that may become available, and that is the nitrate that is developed by the action of electricity upon the nitrogen of the air and certain chemicals or minerals. This has not yet developed to be of economic importance, and while in the opinion of some eminent scientific men, the time may not be far distant when we may economically produce nitrate by electricity, we have not yet reached that point.

At the request of our president, I have compiled this review of the present state of our knowledge of the nitrate problem. I could not, without occupying too much of your time, go into the details of many other laborious investigations, carried on in many countries by careful and patient scientific men. What I have said is classified as follows :

(1) The sodium nitrate is the most important source from which available nitrogen can be supplied, at the present time. I have given you some account of the sources of supply, and the character and uses of the finished product as it comes into the market.

(2) The rôle that nitrate plays in agriculture.

(3) The efforts of scientific men to provide it, or furnish a substitute for it.

(4) Scientific investigations bearing upon it, showing at considerable length the important relations of bacterial life to its production and destruction.

In conclusion, I may say that science has failed, so far, to provide a substitute for the natural nitrate, and it is more economical to avail ourselves of the reserve supplies, representing the accumulated work of bacterial ferments during protracted geological periods of the past, in the now desert regions of Chili, than it is to rely upon their inadequate and uncertain work in our soils under the unfavorable natural conditions prevailing in our climate.

JOHN A. MYERS.

NOTES.

On a Possible Error in the Determination of Nitrogen in Nitrates Due to Impurities in Reduced Iron.—Reduced iron is employed in two of the methods for the determination of nitrogen in nitrates, which are in use by the Association of Official Agricultural Chemists. Recently, in making blank determinations with a new lot of so-called chemically pure reduced iron it was found that, by the modified Ulsch method, much less ammonia was required for neutralizing the acid than in the case of blank tests formerly made. The error from this cause in determinations involving half a gram of commercial sodium nitrate, would amount to from 0.30 to 0.35 of a per cent. By direct distillation, without first allowing the iron to dissolve in the acid, no difficulty was experienced. The reduced iron bore the label of one of the leading manufacturers of chemicals in Germany and was ordered through a prominent and reliable firm in this country.

Since these tests were made, an account of a similar observation by L. Brandt¹ has been noticed. Brandt found in a similar manner an error equal to eight-tenths of a per cent., assuming half a gram of nitrate to be employed in a single test. As in our own case, he assured himself that the error was not due to any of the other reagents, nor to the apparatus employed, and also found that the error did not appear unless the iron was dissolved in the acid before the distillation. From various tests made by Brandt, he concluded that the impurity in the iron was in the form of some organic nitrogen compound, which probably gained access to it, subsequent to its reduction by hydrogen. Further experiments showed that the impurity could be removed by heating the iron in a current of hydrogen, though the accom-

¹ *Chem. Ztg.*, 23, 22 (1899).