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RELATION OF CHEMISTRY TO AGRICULTURE[1]

THE subject assigned the writer on the program of exercises in honor of Dr. W. A. Noyes, who was recently appointed head of the department of chemistry and director of the laboratory at the University of Illinois, is "The Relation of Chemistry to Agriculture."

The friends of the university, who are present here on this auspicious occasion, will, as a matter of course, not expect anything new or startling in a paper of this kind. The application of chemistry to the art of agriculture is characterized by the same results which are manifest in many of the leading industries of the world after this fundamental science had thrown new light upon the processes involved. One general and most important result in this connection has been the establishment of rationalism in the place of empiricism.

It is true that in some of the methods employed in agriculture empiricism has been in advance of science. The beneficial effects of barn-yard manure upon crops was well established in the minds of farmers before chemistry had pointed out that carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, potassium, calcium, magnesium and iron were essential to vegetable

[1] This and the following addresses by William McMurtrie, Julius Stieglitz, George B. Frankforter and William A. Noyes were delivered at the inaugural exercises of Professor Noyes as head of the chemical department and director of the chemical laboratory of the University of Illinois, on October 18, 1907.

growth. So also the addition of the more concentrated feeding stuffs, as cereals to hay, straw, roots, etc., in the feeding of domestic animals, was learned by simple observation to be useful in the production of milk, flesh, fat, work, etc., before science had established the fact that the best results could be attained only by the proper proportion in a ration of digestible protein, fat, carbohydrates and ash.

The history of nations, with the exception of one, shows, however, that these empirical observations were not universally put to practise by the tillers of the soil. The capability of a rich virgin soil to produce remunerative crops for a generation or more led to the baneful waste of most fertilizing materials in the past. As a result of this practise the population of many nations increased and civilization advanced until the bountiful sources of plant food contained in the soil became exhausted to such an extent that an adequate amount of food for the teeming populations could no longer be produced, and retrogression in every respect necessarily followed.

The population of countries stands in a direct relation to the food-supply, other things being equal. When the food supply of the territory now occupied by our beloved country was limited to hunting and fishing with a very insignificant amount of agricultural crops, this vast domain could support a population of only about three millions of people. With the advent of the white race and the gradual subjection of the fertile soils to agricultural pursuits, this territory now supports a population of eighty millions of people and the limit has not yet been reached.

It is the province of agriculture to utilize a comparatively few, special, inorganic forms of matter contained in the air and soil and change them into organic compounds, vegetable and animal, which may serve as food and raiment for mankind. Since the transformation which matter thus undergoes is of a purely chemical nature, it stands to reason that the science of chemistry was destined to free agriculture from the slough of empiricism in which it was engulfed and place it upon a sound, scientific basis. The minds of many of the most prominent chemists of the world were imbued with the importance of study and investigations leading to this end. As a result of their labors truths were gradually established and rational systems in the production of vegetable and animal matter based upon them were inaugurated. On this occasion, therefore, it will only be possible to refer briefly to the more important services which the science of chemistry has done to increase and perpetuate the food production of the world.

About three quarters of a century ago Liebig, who is generally regarded as the father of agricultural chemistry, penned the following words:

> A visible, gradual deterioration of arable soils of most civilized countries can not but command the serious attention of all men who take an interest in the public welfare. It is of the utmost importance that we do not deceive ourselves respecting the danger indicated by these signs as threatening the future of populations. An impending evil is not evaded by denying its existence or shutting our eyes to the signs of its approach. It is our duty to examine and appreciate the signs.

After this acute observer and far-seeing philosopher had uttered these words and published his first little book, entitled "Chemistry in its Application to Agriculture," which marks a new epoch in the history of this important branch of human industry, and Wiegeman and Polsdorf had corroborated the theoretical views of the great master by furnishing the infallible, experimental proof, that the mineral or ash constituents of plants were indispensable to vegetable growth, the intelligent farmers of Germany were eager to listen to Liebig's teaching and to profit by any

light which the more accurate and rational methods of science might furnish. They had been educated in the school of experience, in which they learned that the closest attention, the most arduous labor and the strictest economy were demanded to extort from their impoverished soils enough to sustain themselves and families. But not only this. The views of Liebig spread rapidly all over the civilized world, and aroused an enthusiasm among scientific investigators in every civilized country, rarely equaled in the annals of history. It is impossible in the time allotted to this paper to go into detail. Suffice it to say that the combined efforts of all these investigators have done more for public welfare than perhaps any other human undertaking. Among the important results of their labors in connection with soil and vegetable production may be mentioned:

1. The chemical composition of agricultural products, including the ash or mineral ingredients.

2. The chemical composition of soils, showing that the soil contains certain elements which serve as plant food and without which vegetable growth is impossible.

3. The establishment of the fact that the most important of the ingredients of plant food, *i. e.*, those which furnish the bulk of the ash of agricultural crops, and contained in the soil in comparatively small quantities, that they are present in two forms, available and reserve plant food, that the immediate fertility of soils depends upon the former, and that by continuous cropping without application of fertilizing materials to the soil this available plant food is gradually exhausted, until maximum or even average crops can no longer be produced.

4. The important observation that if only one of the essential elements of plant food is wanting in the soil, while all others are present in ample quantities, plants will refuse to grow.

5. The devising of methods by which the wanting ingredients of plant food can be definitely determined in an exhausted soil, so that the loss of money and labor in applying fertilizers, which would have no beneficial effect upon the production of crops, can be avoided.

6. The discovery and analysis of natural deposits of plant food, as Guano, Chili saltpeter, Stasfurt salts, apatites, coprolites, limestones rich in phosphates, etc., as well as the analysis of numerous waste products and by-products, such as bones, blood, tankage, oil meals, wood ashes, etc., all of which have been utilized in immense quantities, the world over, for restoring worn-out soils.

7. The control of commercial fertilizers, giving the true composition and money value of the brands brought by manufacturers and dealers upon the market, in order to protect the former against frauds, so easily practised in articles of this nature.

8. The composition, production, proper treatment and preservation of barnyard manure, the most important, most easily obtainable and the best of all fertilizing materials.

9. The chemical composition of all agricultural products, giving an insight into the nature and amount of plant food removed by them from the soil, and indicating a proper rotation of crops, so that one or the other of the essential ingredients of plant food may not be too rapidly withdrawn from the soil, and thus unduly hasten its unproductiveness.

These, my friends, are some of the beneficent results which have followed the application of chemistry to the production of vegetable matter. In passing over to the consideration of the other branch of agricultural industry, namely, the production of animal matter, it may be well to call

attention to a few well-known facts. Plants can live on the dead inorganic matter contained in the air and soil alone. They have the power of transforming it into living organic matter and into the more complicated combinations of which their bodies are composed. Animals can not live on inorganic matter alone. They must have in addition the more highly organized forms, which plants produce. Hence the animal kingdom is dependent upon the vegetable kingdom for its existence.

Since animals consume plants for food, it follows that the same elements which occur in plants are found in the animal body. In fact the same compounds that occur in vegetable matter are again found in the animal body, only slightly modified.

Before chemistry began to shed its light upon agriculture, the rearing and feeding of domestic animals for human food and raiment was just as empirical as the production of plants. It is true, as already stated, that simple observation led to many good methods in actual practise, but no intelligent reasons could be given for the methods. The subject of animal nutrition was taken up by scientific investigators with as much zeal and as careful study and experimentation as were expended on vegetable production, and the results and data obtained are sufficient to warrant an intelligent use of the means at hand.

The amount of time and labor expended in changing the rule-of-thumb methods of feeding domestic animals into a rational system is very great taken in the aggregate.

1. The composition of every product of domestic animals, the composition of every part of their bodies, and the proportion of these parts among themselves in forming the living animals produced for various purposes are known to the chemist.

2. The proximate composition of feeding stuffs of all kinds has been accurately determined by thousands upon thousands of analyses made in all parts of the world. Extensive tables giving the percentage of protein, fat, carbohydrates, fiber and ash have been placed at the command of every one engaged in this branch of agriculture. But this is not all. Just as the total amount of plant food in the soil is not completely available for the production of vegetable matter, so the proximate principles just mentioned do not entirely serve as nourishment for the animal body. The digestibility of the various ingredients varies in different plants as well as in different parts of the same plant. Hence a simple analysis of a feeding stuff does not always determine its true food value. For this reason additional investigations were found to be necessary. Just as in the determination of the available plant food of a soil the plants are brought into requisition, so here experiments had to be made in connection with various domestic animals in order to determine the amount of these ingredients which served as nourishment when taken into the system. Tables giving the coefficients of digestion of the constituents of the feeding stuffs, therefore, always accompany the tables of analyses. In addition to all this, experiments have been made with domestic animals to establish the best proportion and amount of these constituents for the purpose of maintenance and development as well as for the production of work, milk, flesh, fat, etc.

3. As in the case of commercial fertilizers, here again the work of the chemist controls the sale of concentrated feeding stuffs, so that the purchaser of these valuable commodities, which are thrown upon the market in immense quantities, is insured against adulteration.

With all of this information at his com-

mand the intelligent animal husbandman can utilize his store of feeding stuffs, and, if necessary, by purchasing others, prepare the proper rations for insuring the best and most economical results.

Chemistry has aided agriculture in many other ways. The establishment of new industries like the manufacture of glucose, which annually insures a market for the surplus production of agricultural crops, may be mentioned. Of much greater importance to agriculture has been the establishment of the beet-sugar industry, since it opened a field for the production of a new agricultural crop on an immense scale. From an almost hopeless beginning this industry has by the aid of science gradually grown into one of the leading industries of the world.

When the German chemist, Margraf, examined the garden beet it was found to contain only about four or five per cent. of cane sugar. By careful selection and analysis of mother beets, selecting only those for seed which revealed the highest content of sugar, the quality of this sugar-producing plant was gradually improved. When the writer was a student Professor Wagner, the celebrated technologist of Germany, found, upon analysis, individual beets with a sugar content of twelve per cent. He at that time expressed the hope that by continued effort in the improvement of the beet this exception might prove to be the rule. The results to-day far exceed his expectations. Individual beets have been grown with a sugar content of twenty per cent., and it is safe to say that in the best sugar-beet countries the average content of sugar of beets delivered at the factories reaches sixteen per cent. The gradual improvement in the quality of this plant can be seen from the following statistics. For the production of one ton of sugar there were required:

In 1836	18 tons of beets.
In 1842	16 tons of beets.
In 1857	12 tons of beets.
In 1871	11 tons of beets.
In 1894	7½ tons of beets.

At the present time under favorable conditions less than seven and one half tons of beets are undoubtedly required to manufacture a ton of sugar. To show how this industry has grown in importance it is only necessary to say that of the total production of sugar of the world in 1905, amounting in round numbers to thirteen millions of tons, seven millions of tons were produced from sugar beets.

Other plants are no doubt capable of a similar improvement, and in this connection the writer refers with great pleasure to the work of, and result in, corn-breeding inaugurated by Professor Hopkins, of this institution. The production of corn rich in starch for the manufacture of starch, alcohol and glucose, and rich in protein for the stock-feeder, will add immensely to the value and usefulness of this staple crop.

Chemistry has rendered a great service to agriculture in furnishing the means of combating the insect and other enemies of fruits and crops of various kinds.

The liberal use of insecticides and fungicides has saved many agricultural crops from utter annihilation and has been instrumental in greatly increasing the yield and improving the quality of agricultural products.

Weeds constitute another enemy of the farmer's crops. Where cultivation can be employed throughout the growing season weeds can, of course, be kept down. But in the growing of small grains and grasses this method of destroying them is impossible. In some countries the yield and quality of this class of crops are greatly reduced by weeds. But chemistry has apparently found a way to remedy this difficulty. The latest achievement in this

respect is to spray the growing crop with the solution of a chemical which kills the weeds and does not injure the crop. The chemical employed for this purpose is ferrous sulphate in a ten-per-cent. solution. It does not injure cereals, corn or even grasses and clover, but destroys or retards the growth of the most noxious weeds to such an extent that the yield of crops has been increased twenty per cent.

One of the greatest services which chemistry has rendered to the amelioration of the farmer's vocation is the protection assured against artificial and fraudulent imitations of numerous genuine products. A few of the most vicious abuses, through which the farmer and consumer suffered alike, were the sale of oleomargarine for genuine butter, which almost destroyed the dairy industry; the sale of artificially colored distilled vinegar for cider vinegar, which caused millions of bushels of apples to rot in the orchards of the country; the sale of glucose for maple syrup and honey; the sale of skim milk for whole milk; and the sale of skim-milk cheese for full cream cheese.

It is gratifying to refer to the aid which the governments of all civilized nations have given in recent times for the purpose of elevating and perpetuating the art of agriculture, the industry most important to the welfare of humanity. Agricultural colleges and experiment stations, agricultural departments, both national and state, have been established and richly endowed. These are filled with earnest and honest investigators, who are working diligently and faithfully to disseminate truths, already established, among the rural population and to discover new ones, by which this noble vocation may be advanced. May the good work go on.

H. A. Webber

Relation of Chemistry to the Industries

I am gratified that an opportunity has been given me to be present on this occasion and take part in the installation of the new head of the department of chemistry of this great university. To me it is a matter of no little significance, and to all of us, interested, as we are, in the promotion of the work of the institution and its material and scientific progress, it is almost the beginning of a new era in its development. We may congratulate ourselves that the officers charged with the duty of seeking out and appointing the new incumbent, should have had such good fortune in their search, and should have chosen so well. But I know you will sympathize with me when I say that the pleasure and gratification which comes to us now must be tempered by the remembrance of the real cause which brings us together: the early and untimely removal of the late head of the department. To me it brought keen sorrow. I knew Dr. Palmer as a youth, just emerging into manhood. Earnest, enthusiastic, industrious and skilful, he came to his work with qualities of mind calculated to make him a leader among his fellows, and to cause him to quickly take a high position in his chosen profession. A persistent reader of the literature even in his student days, a deep and accurate thinker, a rapid manipulator, confident of the accuracy of his results, he was able to accomplish more within a given time than most men; and all this, combined with a vivid and useful imagination, made possible for him splendid progress in research and opened for him a career which must certainly have placed him in the forefront of the profession, and made him a leading chemist in his country and in the world.

As a teacher the same qualities made him successful. Students respect and follow