CHEMISTRY IN FARM OVERALLS

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It is well known that chemistry has been of service to mankind in many ways for many years. Consequently at the present time there are various degrees of its service or of the further application of its usefulness to humanity. In some lines of chemistry long and intensive study has so thoroughly developed its scope that it offers little attraction for new achievements and hence has been called "dead chemistry." Farm chemistry, on the other hand, is only in its infancy and can well be called not only "live" but "living" chemistry, as the life processes themselves constitute its main problems. Very difficult problems they are, but attempts at their solution are very fascinating. The applications of chemistry to agriculture are numerous but the writer has chosen about a half a dozen phases which seem worthy of special notice and he will discuss each briefly.

The Farmer as a Manufacturer. It is important that every farmer should become acquainted with the products he manufactures as it adds greater interest and may increase the quality of his products and also his profits. If one were to try to enlighten a savage as to what a potato is by telling him it is the result of a summer's sunshine, warm rains, two square feet of ground mixed on the surface with some laboratory ingredients, all combined with some experience in growing potatoes—the savage would conclude that it was all magic—which, in truth, growing food products really is. However, when agriculture is considered as a plant for the manufacturing of crude organic chemical compounds, which corn, hay, fruits, straw, apples, potatoes, etc, may well be considered, a new era in agriculture will have arrived. Then all surplus raw material produced will be used as profitable by-products. Corn will not then be grown for the ear only, clover will not be plowed under for the nitrogen and humus. Wheat and straw will be equally valuable, wood will be changed to gaseous fuel for stove and tractor and farm surplus and waste will be a relic of the past.

Proteins: The Farmer's Easy Money. The products of the farmer's chemical factory are carbohydrates, fats, proteins, minerals, and closely related substances, all of which are manufactured from the soil, sunshine, air and water, in about the proportion of 5 lbs. of soil, 600 hours of sunshine, 20 lbs. of air and 75 lbs. of water per 100 lbs. of finished product. These compounds are present in an average man to the extent, approximately, of water 90 lbs. minerals 8.4 lbs., fat 23 lbs. and protein 27 lbs. Thus protein makes up the largest part of the solid matter of man or animal. Also it is the constituent which brings the greatest profit when marketed as proteins sell for about five times as much as carbohydrates and two to three times as much as fats. Proteins are made by plants which receive most of their nitrogen in gaseous form from the air and by the aid of bacteria contained in the nodules on the roots. The nodules from soy beans are shown in Fig. 1. These microscopic organisms are the farmer's best friends as they produce free of charge his most valuable products. From gaseous nitrogen, the bacteria,

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at the farmer's bidding, are able to combine nitrogen into complex plant proteins and thus to manufacture a product so complicated as to baffle all other efforts for its production. The farmer's carbohydrate market is being attacked by synthetic products but there is still no competition for his proteins.

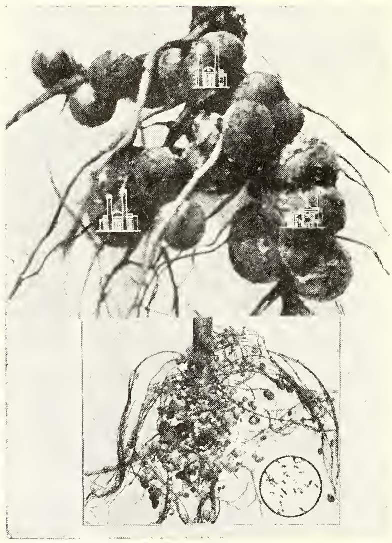

Fig. 1—(After Ill. Circ. 326)

Sunshine, Corn and Enzymes. When a farmer plants corn a complicated chain of chemical reactions is started. The seed, containing at first about 10 to 12 percent water soon holds 20 to 25 percent. This starts enzyme action in the grain and the starch is gradually changed to sugar as follows:

$$\underset{\text{starch}}{(C_6H_{10}O_5)_x}+\underset{\text{amylases}}{H_2O} \rightarrow \underset{\text{dextrin}}{(C_5H_{10}O_6)_x} \rightarrow \underset{\text{maltose}}{C_{12}H_{22}O_{11}} \rightarrow \underset{\text{glucose}}{2C_6H_{12}O_6}$$

Proteins may decompose to amino acids and alcohol, produced by bacteria or yeasts as in reaction.

$$\underset{\text{leucine}}{R{\cdot}CH{\cdot}NH_2{\cdot}COOH}+H_2O \rightarrow \underset{\text{alcohol}}{R{\cdot}CHOH{\cdot}COOH}+NH_3$$

The fat which has been stored in the seed is oxidized to a sugar to help nourish the seedling, as follows:

$$\underset{\text{palmatin}}{2C_3H_5(OOC\ C_{15}H_{31})_3}+85\ O_2(H_2O) \rightarrow \underset{\leftarrow\text{dextrose}}{10\ C_6H_{12}O_6}+42\ CO_2+38\ H_2O$$

All these reactions and many more are set in motion when the seed is placed in moist soil. Soon the seed exhausts its supply of nourishment and calls upon the soil and air to keep the corn factory going. This is shown in Fig. 2.

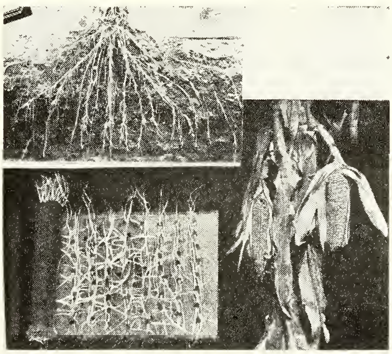

Fig. 2—(After Minn. Ext. Circ. 58)

Aluminum Indigestion in Corn Plants. When the roots of plants make their way through acid soils, they frequently take into their digestive system more aluminum and iron than would have been absorbed if the soil were less acid. These combine with the protein in the nodes of the corn stalks and close the passage

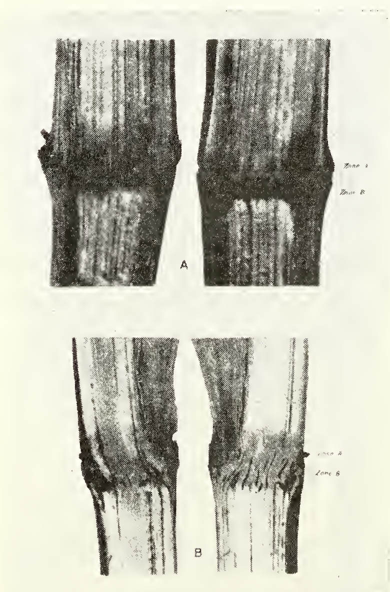

Fig. 3—(After Haffer and Carr)

ways for food movement. Hence the plant developes a bad case of indigestion. The blackened and open channels are shown in Fig. 3. The corn is quite sensitive to such interference with its cell functions and shows signs of this disturbance by developing a light green color, by marginal firing of the leaves and by poor ear development. The farmer can overcome this trouble somewhat by causing the soluble aluminum compounds to be converted into less soluble ones by the addition of limestone and acid phosphate. This produces an extensive chemical change over a large area and protects future plants from developing aluminum indigestion.

Chemical Reactions Follow the Plow. The changes taking place in soil composition through the agencies of bacteria, yeast, molds, lichens, nematodes, oxidation, hydrolysis, etc., are numerous and not well understood. After the soil has been disturbed by the plow, the many new reactions which are started and the old ones which are speeded up may often be observed by the naked eye. The soil has a greenish color when plowed but upon oxidation by exposure to sun and air for a day or two, it turns to yellow and then to a reddish color. This is due largely to the oxidation of the iron from ferrous to ferric compounds. Ferrous oxide (FeO) is green colored and the hydrated iron compound limonite ($2Fe_2O_3 3H\ O$) is yellow, whereas the non-hydrated hematite (Fe_2O_3) is red. Oxides of manganese often color white clay soils black or brown, depending on the quantity present, giving them the appearance of soils made fertile by the addition of organic matter. Sulphates present in a soil may be changed by coming in contact with organic matter as follows:

$$4C_3H_6O_3+CaSO_4 \rightarrow 4C_2H_4O_2+CaS+4CO_2+4H_2$$

The free hydrogen causes reduction of some of the oxides, while the CO_2 released tends to form acid carbonates and to make phosphates more soluble as follows:

$$Ca_3PO_4+4H_2CO_3 \rightarrow Ca(H_2PO_4)_2+Ca(HCO_3)_2.$$

Thus every furrow turned by the plow starts a chain of reactions that profoundly alter the soil composition and rid it of much of last year's vegetation.

Hay Making Developes Perfumes. Those not familiar with the making of hay seldom realize that it is any more than a drying process which is to prevent spoiling when the hay is placed in the barn. This change in water content is only one of the many reactions set up during the drying period. When clover is cut for hay it may contain as much as 75 percent water. Part of it is loosely held and may be squeezed out by grinding and pressing, the rest is bound and is intimately combined with proteins, oils, glucosides, tannins, etc., in the plant. Hence when the plant is cut by the farmer, Fig. 4, a succession of reactions is started which are not understood, but the developement of heat, and odor, and the change in color are unmistakable evidences of drastic rearrangements going on within the plant. The loss of water on cutting starts an enzyme action which in turn releases an ester called coumarin which has the odor of new mown hay. The change in color from the familiar dark green to the pale green is thought to be produced by the action of another group of enzymes which act on the chloraphylls a and b in the presence of sunlight. Experience has shown that to produce well "cured" clover hay it is desirable to pile the hay in cocks after it has been partly dried and to let the curing go on "in the shade," being careful to avoid hasty drying. In this way the heat which developes favors the formation by enzymes of large quantities of pleasing odors which add greatly to its relish by animals and prevent oxidation of the pigment through exposure to sunlight. Properly cured hay will sweat in the stack or mow unless it is loosely and unevenly packed but this will add to the desirable flavor. The development of flavor by the action of enzymes on tea leaves is usually more carefully carried out than in hay making, since the animals

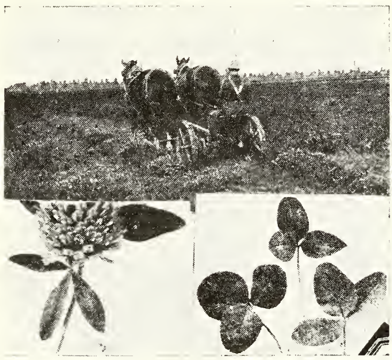

Fig. 4—(After Minn. Ext. Circ. 47)

which consume the cured product are more capable of registering their objections to poor quality. Most of Nature's packages, as apples, oranges, etc., are put up in well planned fibrous bundles with enough flavor, color and odor to add spice and variety and make life more pleasant and interesting.

Farming is Largely, Producing Chemical Reactions. As one goes about the farm from day to day with eyes trained to observe changes of a chemical nature, such as the souring of milk, the liming of soil, the rusting of iron, the burning of wood, the fertilizing of corn, the rotting of manure, the fermenting of silage, the weathering of rock, the ripening of fruit and grain, the heating of hay and grain, the changing of oats and hay by the horse to energy to pull a plow, or the changing of green grass to white milk by the cow, he sees things which are truly magical, but yet real and being constantly repeated.

Thus it is that the man in farm overalls is a production chemist of the world's greatest and most important industry.