Relation Of Bacteria To Agriculture

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We have already noticed that bacteria play an important part in some of the agricultural industries, particularly in the dairy. From the consideration of the matters just discussed, it is manifest that these organisms must have an even more intimate relation to the farmer's occupation. At the foundation, farming consists in the cultivation of plants and animals, and we have already seen how essential are the bacteria in the continuance of animal and plant life. But aside from these theoretical considerations, a little study shows that in a very practical manner the farmer is ever making use of bacteria, as a rule, quite unconsciously, but none the less positively.

SPROUTING OF SEEDS

Even in the sprouting of seeds after they are sown in the soil bacterial life has its influence. When seeds are placed in moist soil they germinate under the influence of heat. The rich albuminous material in the seeds furnishes excellent food, and inasmuch as bacteria abound in the soil, it is inevitable that they should grow in and feed upon the seed. If the moisture is excessive and the heat considerable, they very frequently grow so rapidly in the seed as to destroy its life as a seedling. The seed rots in the ground as a result. This does not commonly occur, however, in ordinary soil. But even here bacteria do grow in the seed, though not so abundantly as to pro-duce any injury. Indeed, it has been claimed that their presence in the seed in small quantities is a necessity for the proper sprouting of the seed. It has been claimed that their growth tends to soften the food material in the seed, so that the young seedling can more readily absorb it for its own food, and that without such a softening the seed remains too hard for the plant to use. This may well be doubted, however, for seeds can apparently sprout well enough without the aid of bacteria. But, nevertheless, bacteria do grow in the seed during its germination, and thus do aid the plant in the softening of the food material. We can not regard them as essential to seed germination. It may well be claimed that they ordinarily play at least an incidental part in this fundamental life process, although it is uncertain whether the growth of seedlings is to any considerable extent aided thereby.

THE SILO

In the management of a silo the farmer has undoubtedly another great bacteriological problem. In the attempt to preserve his summer-grown food for the winter use of his animals, he is hindered by the activity of

common bacteria. If the food is kept moist, it is sure to undergo decomposition and be ruined in a short time as animal food. The farmer finds it necessary, therefore, to dry some kinds of foods, like hay. While he can thus preserve some foods, others can not be so treated. Much of the rank growth of the farm, like cornstalks, is good food while it is fresh, but is of little value when dried. The farmer has from experience and observation discovered a method of managing bacterial growth which enables him to avoid their ordinary evil effects. This is by the use of the silo. The silo is a large, heavily built box, which is open only at the top. In the silo the green food is packed tightly, and when full all access of air is excluded, except at its surface. Under these conditions the food remains moist, but nevertheless does not undergo its ordinary fermentations and ;putrefactions, and may be preserved for months without being ruined. The food in such a silo may be taken out months after it is packed, and will still be found to be in good condition foi food. It is true that it has changed its character somewhat, but it is not decayed, and is eagerly eaten by cattle.

We are yet very ignorant of the nature of the changes which occur in the food while in the silo. The food is not preserved from fermentation. When the silo is packed slowly, a very decided fermentation occurs by which the mass is raised to a high temperature (1400 F. to 160° F.). This heating is produced by certain species of bacteria which grow readily even at this high temperature. The fermentation uses up the air in the silo to a certain extent and produces a settling of the material which still further excludes air. The first fermentation soon ceases, and afterward only slow changes occur. Certain acid-producing bacteria after a little begin to grow slowly, and in time the silage is rendered somewhat sour by the production of acetic acid. But the exclusion of air, the close packing, and the small amount of moisture appear to prevent the growth of the common putrefactive bacteria, and the silage remains good for a long time. In other methods of filling the silo, the food is very quickly packed and densely crowded together so as to exclude as much air as possible from the beginning. Under these conditions the lack of moisture and air prevents fermentative action very largely. Only certain acid-producing organ-isms grow, and these very slowly. The essential result in either case is that the common putrefactive bacteria are prevented from growing, probably by lack of sufficient oxygen and moisture, and thus the decay is prevented. The closely packed food offers just the same unfavourable condition for the growth of common putrefactive bacteria that we have already seen offered by the hard-pressed cheese, and the bacteria growth is in the same way held in check. Our knowledge of the matter is as yet very slight, but we do know enough to understand that the successful management of a silo is dependent upon the manipulation of bacteria.

THE FERTILITY OF THE SOIL

The farmer's sole duty is to extract food from the soil. This he does either directly by raising crops, or indirectly by raising animals which feed upon the products of the soil. In either case the fertility of the soil is the fundamental factor in his success. This fertility is a gift to him from the bacteria.

Even in the first formation of soil he is in a measure dependent upon bacteria. Soil, as is well known, is produced in large part by the crumbling of the rocks into powder. This crumbling we generally call weathering, and regard it as due to the effect of moisture and cold upon the rocks, together with the oxidizing action of the air. Doubtless this is true, and the weathering action is largely a physical and chemical one. Nevertheless, in this fundamental process of rock disintegration bacterial action plays a part, though perhaps a small one. Some species of bacteria, as we have seen, can live upon very simple foods, finding in free nitrogen and carbonates sufficiently highly complex material for their life. These organisms appear to grow on the bare surface of rocks, assimilating nitrogen from the air, and car-bon from some widely diffused carbonates or from the CO, in the air. Their secreted products of an acid nature help to soften the rocks, and thus aid in performing the first step in weathering.

The soil is not, however, all made up of dis-integrated rocks. It contains, besides, various ingredients which combine to make it fertile. Among these are various sulphates which form important parts of plant foods. These sulphates appear to be formed, in part, at least, by bacterial agency. The decomposition of proteids gives rise, among other things, to hydrogen sulphide (H,S). This gas, which is of common occurrence in the atmosphere, is oxidized by bacterial growth into sulphuric acid, and this is the basis of part of the soil sulphates. The deposition of iron phosphates and iron silicates is probably also in a measure aided by bacterial action. All of these processes are factors in the formation of soil. Beyond much question the rock disintegration which occurs everywhere in Nature is chiefly the result of physical and chemical changes, but there is reason for believing that the physical and chemical processes are, to a slight extent at least, assisted by bacterial life.

A more important factor of soil fertility is its nitrogen content, without which it is completely barren. The origin of these nitrogen ingredients has been more or less of a puzzle. Fertile soil everywhere contains nitrates and other nitrogen compounds, and in certain parts of the world there are large accumulations of these compounds, like the nitrate beds of Chili. That they have come ultimately from the free atmospheric nitrogen seems certain, and various attempts have been made to explain a method of this nitrogen fixation. It has been suggested that electrical discharges in the air may form nitric acid, which would readily then unite with soil ingredients to form nitrates. There is little reason, however, for believing this to be a very important factor. But in the soil bacteria we find undoubtedly an efficient agency in this nitrogen fixation. As al-ready seen, the bacteria are able to seize the free atmospheric nitrogen, converting it into nitrites and nitrates. We have also learned that they can act in connection with legumes and some other plants, enabling them to fix atmospheric nitrogen and store it in their roots. By these two means the nitrogen ingredient in the soil is pre-vented from becoming exhausted by the processes of dissipation constantly going on. Further, by some such agency must we imagine the original nitrogen soil ingredient to have been derived. Such an organic agency is the only one yet discerned which appears to have been efficient in furnishing virgin soil with its nitrates, and we must therefore look upon bacteria as essential to the original fertility of the soil.

But in another direction still does the farmer depend directly upon bacteria. The most important factor in the fertility of the soil is the part of it called humus. This humus is very complex, and never alike in different soils. It contains nitrogen compounds in abundance, together with sulphates, phosphates, sugar, and many other sub-stances. It is this which makes the garden soil different from sand, or the rich soil different from the sterile soil. If the soil is cultivated year after year, its food ingredients are slowly but surely exhausted. Something is taken from the humus each year, and unless this be replaced the soil ceases to be able to support life. To keep up a constant yield from the soil the farmer under-stands that he must apply fertilizers more or less constantly.

This application of fertilizers is simply feeding the crops. Some of these fertilizers the farmer purchases, and knows little or nothing as to their origin. The most common method of feeding the crops is, however, by the use of ordinary barnyard manure. The reason why this material contains plant food we can understand, since it is made of the undigested part of food, together with all the urea and other excretions of animals, and contains, therefore, besides various minerals, all of the nitrogenous waste of animal life. These secretions are not at first fit for plant food. The farmer has learned by experience that such excretions, before they are of any use on his fields, must undergo a process of slow change, which is sometimes called ripening. Fresh manure is sometimes used on the fields, but it is only made use of by the plants after the ripening process has occurred. Fresh animal excretions are of little or no value as a fertilizer. The farmer, therefore, commonly allows it to remain in heaps for some time, and it undergoes a slow change, which gradually converts it into a condition in which it can be used by plants. This ripening is readily explained by the facts already considered. The fresh animal secretions consist of various highly complex compounds of nitrogen, and the ripening is a process of their decomposition. The proteids are broken to pieces, and their nitrogen elements reduced to the form of nitrates, leucin, etc., or even to ammonia or free nitrogen. Further, a second process occurs, the process of oxidation of these nitrogen compounds already noticed, and the ammonia and nitrites resulting from the decomposition are built into nitrates. In short, in this ripening manure the processes noticed in the first part of this chapter are taking place, by which the complex nitrogenous bodies are first reduced and then oxidized to form plant food. The ripening of manure is both an analytical and a synthetical process. By the analysis, proteids and other bodies are broken into very simple compounds, some of them, indeed, being dissipated into the air, but other portions are retained and then oxidized, and these latter become the real fertilizing materials. Through the agency of bacteria the compost heap thus becomes the great source of plant food to the farmer. Into this compost heap he throws garbage, straw, vegetable and animal substances in general, or any organic refuse which may be at hand. The various bacteria seize it all, and cause the decomposition which converts it into plant food again. The rotting of the compost heap is thus a gigantic cultivation of bacteria.

This knowledge of the ripening process is further teaching the farmer how to prevent waste. In the ordinary decomposition of the compost heap not an inconsiderable portion of the nitrogen is lost in the air by dissipation as ammonia or free nitrogen. Even his nitrates may be thus lost by bacterial action. This portion is lost to the farmer completely, and he can only hope to replace it either by purchasing nitrates in the form of commercial fertilizers, or by reclaiming it from the air by the use of the bacterial agencies already noticed. With the knowledge now at his command he is learning to prevent this waste. In the decomposition one large factor of loss is the ammonia, which, being a gas, is readily dissipated into the air. Knowing this common result of bacterial action, the scientist has told the farmer that, by adding certain common chemicals to his decomposing manure heap, chemicals which will readily unite with ammonia, he may retain most of the nitrogen in this heap in the form of ammonia salts, which, once formed, no longer show a tendency to dissipate into the air. Ordinary gypsum, or superphosphates, or plaster will readily unite with ammonia, and these added to the manure heap largely counteract the tendency of the nitrogen to waste, thus enabling the farmer to put back into his soil most of the nitrogen which was extracted from it by his crops and then used by his stock. His vegetable crops raise the nitrates into proteids. His animals feed upon the proteids, and perform his work or furnish him with milk. Then his bacteria stock take the excreted or refuse nitrogen, and in his manure heap turn it back again into nitrates ready to begin the circle once more. This might go on almost indefinitely were it not for two facts : the farmer sends nitrogenous material off his farm in the milk or grains or other nitrogenous products which he sells, and the de-composition processes, as we have seen, dissipate some of the nitrogen into the air as free nitrogen.

To meet this emergency and loss the farmer has another method of enriching the soil, again depending upon bacteria. This is the so-called green manuring. Here certain plants which seize nitrogen from the air are cultivated upon the field to be fertilized, and, instead of harvesting a crop, it is ploughed into the soil. Or perhaps the tops may be harvested, the rest being ploughed into the soil. The vegetable material thus ploughed in lies over a season and enriches the soil. Here the bacteria of the soil come into play in several directions. First, if the crop sowed be a legume, the soil bacteria assist it to seize the nitrogen from the air. The only plants which are of use in this green manuring are those which can, through the agency of bacteria, obtain nitrogen from the air and store it in their roots. Second, after the crop is ploughed into the soil various decomposing bacteria seize upon it, pulling the compounds to pieces. The carbon is largely dissipated into the air as carbonic dioxide, where the next generation of plants can get hold of it. The minerals and the nitrogen remain in the soil. The nitrogenous portions go through the same series of decomposition and synthetical changes already described, and thus eventually the nitrogen seized from the air by the combined action of the legumes and the bacteria is converted into nitrates, and will serve for food for the next set of plants grown on the same soil. Here is thus a practical method of 'using the nitrogen assimilation powers of bacteria, and reclaiming nitrogen from the air to replace that which has been lost.

Thus it is that the farmer's nitrogen problem of the fertile soil appears to resolve itself into a proper handling of bacteria. These organisms have stocked his soil in the first place. They convert all of his compost heap wastes into simple bodies, some of which are changed into plant foods, while others are at the same time lost. Lastly, they may be made to reclaim this lost nitrogen, and the farmer, so soon as he has requisite knowledge of these facts, will be able to keep within his control the supply of this important element. The continued fertility of the soil is thus a gift from the bacteria.