Studies on the cellulose.*

(Publication on cellulose No. I.)

By

Arao Itano.

[Aug. 13th, 1926.]

This paper presents a preliminary report on the bio-physico-chemical problems which are in course of investigation on the cellulose.

Cellulose is one of the most important carbohydrates from many standpoints, namely its wide distribution in nature and its usefulness in manufacturing. Especially in agriculture, the important rôle in maintenance of proper soil conditions has been well known. It however has been very little known as to its exact chemical nature on account of its peculiar properties. Through the thermodynamical studies together with the investigations on the process of decomposition, some additional information may be obtained.

Cellulose is decomposed by comparatively few microorganisms in spite of the enormous amounts of cellulose produced and destroyed every year on earth. Among the few organisms isolated, the anaerobic group has been investigated[1] to some extent as to their activity. But the others received comparatively little attention in recent years.[2] An aerobic, thermophilic cellulose fermenter has been investigated here in regard to their energetics, intermediate and end-products of the fermentation.

In regard to the studies of energetics on the members of Schizophyta, only few literature is available. Since RUBNER[3] investigated the subject, there has been very little work done. Especially on the soil microorganisms, only few investigation are found on record.[4]

---

1) OMELIANSKI, Centralbl. f. Bakt., II, 1902, 193.
2) C. van ITERSON, Centralbl. f. Bakt., II, 23, 689;
HUTCHINSON & CLAYTON, J. Agr. Science, 9, 143;
MCBETH & SCALES, U. S. Dep't Agr. B. P. I. Bull., 266;
VILJOIN & others, J. Agr. Science, 16, 1926, 1 : and others.
3) M. RUBNER, Archiv. f. Hygine, 48, 1904, 260. 57, 1906, 161.
A. PUTTER, Vergleichende Physiologie, 1911, 37.
4) S. WINOGRADSKY, Bot. Zeitung, 45, 1187, 489;
N. L. SOHNGEN, Centralbl. f. Bakt., 15, 1906, 513;
F. H. van SUCHTELEN, Centralbl. f. Bakt., 2, 58, 1923.

* Published in the Bull. of the Agricultural Chemical Soc. of Japan II, 5, 54, May, 1926.

I. Thermodynamics Involved in the Cellulose Decomposition.

As it is well known, the plants synthesize the cellulose out of carbon dioxide and water, and when the plant residues find their way into the soil, they are decomposed by,

1. the enzyme cytase,
2. the anaerobic microorganisms,
3. the aerobic microorganisms,

Of course in the last two cases, the action may be due to the enzyme secreted by the organism, but it has not so far been demonstrated. Again it is not probable that the cytase survives the temperature of 65°C for so long time as the thermophilic cellulose fermenter do unless some special conditions exist. As the end products of decomposition, the carbon dioxide and water are given off. This transformation involves not only bio-chemical but physical process namely the thermodynamics or energetics.

Then, in the process of formation of cellulose, certain amount of energy absorbed or endothermic reaction takes place, and the exothermic reaction follows in course of decomposition. This transformation of energy taking place in soil is very important from the soil microbiological standpoint. That is while the plants utilize the sun's energy in the process of synthesis, the microorganisms must find the energy supply to elsewhere, and the source became more clearly understood by the study of fermentation by RUBNER[3] and few others.

In investigating this phase of problem on the cellulose, it was found very difficult on account of the lack of exact chemical knowledge of cellulose and also the nature of the process involved. For instance, in looking up the literature on the heat of formation and also the heat of combustion, the numerical value given by the different authors is somewhat different. Examining the data collected in the light of energy equation of cellulose and comparing it with that of glucose, one finds that

For

Glucose, $C_6H_{12}O_6 + 12\,O = 6CO_2 + 6H_2O + 677.2$ Kcal[1]

$-x \quad - \quad 0 \quad = -565.8 - 409.8 + 674.0$ „ [2]

and for,

Cellulose, $C_6H_{10}O_5 + 12\,O = 6CO_2 + 5H_2O + 680.4$ Kcal[1]

$-x \quad - \quad 0 \quad = -565.8 - 341.5 + 680.0$ „ [2]

From these equations, the heat of formation[3] is calculated and found as follows: i. e., calculating for x,

---

1) R. BIEDERMANN, Chemiker-Kalender.

2) W. NERNST, Theoretical Chemistry, 6th edition;

3) F. H. GETMAN, Outlines of Theoretical Chemistry, 3rd Edition.

For

Glucose, 301.6 and Cellulose, 227.3 Kcal.

From the heat of formation thus calculated, one may be informed very approximately as to the quantity of energy involved in the synthesis, and also from the heat of combustion, we find the maximum energy could be liberated on its complete oxidation. Further, from the çalorific value determined, the constitution of cellulose may possibly be ascertained more accurately and clearly than has been known.[1] This phase of the investigation will be reported in detail in near future.

In the light of the energy equation, the possible process of cellulose decomposition may be noted as follows, assuming that an initial step is hydrolysis:

$$C_6H_{10}O_5 + H_2O = C_6H_{12}O_6 + x \text{ cal.}$$

In the above equation, the value for x cal. would be very small, and the nature of $C_6H_{12}O_6$ resulted differ by different process. It can be any one of the monosaccharide, namely mannose, galactose, glucose etc. So for as the author is aware, the products of aerobic, cellulose decomposition have not been studied to any extent.

Once the cellulose is hydrolysed into monosaccharide, it offers many possibilities, such as well known reaction, intermolecular etc.,

By an intermolecular reaction:

$$C_6H_{12}O_6 = 2C_2H_5OH + 2CO_2 + 22 \text{ Kcal.}^{2)} = 2C_3H_6O_3 + 15 \text{ Kcal.}^{2)}$$

By further oxidation:

$$C_2H_5OH + 2O = CH_3COOH + H_2O + 115 \text{ Kcal.}$$

Besides these well known, possible reactions, the products produced first may undergo the further decomposition in course of investigation. Consequently the exact processes, and the nature of the products in the cellulose decomposition may never be found out exactly. However an attempt is made here to study the products of aerobic decomposition and thermodynamics involved, and it is hoped to obtain some additional information on the subject, which will be reported in near future.

II. Thermophilic Cellulose Fermenter.

An organism which has received a special attention in the investigation here is an aerobic thermophilic bacteria of which description will appear later.

This organism has been investigated in view of the fact that the aerobic cellulose fermenter has received very little attention in past, although I believe

1) F. H. GETMAN, Outlines of Theoretical Chemistry, 3rd Edition.

2) M. RUBNER, Archiv. f. Hygine, 48, 1904, 260. 57, 1906, 161.
A. PUTTER, Vergleichende Physiologie, 1911, 37.

it plays a very important rôle in the process and subsequently in agriculture. Thermophilic nature of this organism enables it to work at high temperature which is often reached in composting, where the temperature rises up to 75°C often.

III. Practical Application.

In recent years, the study on the rôle of organic matter in soil fertility has become acute.[1] SCHREINER[2] stated "It is only by continually supplying organic matter that the soil-forming, soil fertility promoting, dynamic changes can continue to go on unchecked and undiminished, liberating ammonia and other compounds, *supplying energy* for bacterial life and furthering nitrification and nitrogen fixation". Further the same author stated, "If we would understand soil fertility as influenced by *organic manures*, green manures, and good farming methods we must study not so much the organic content, except it be as a key to these *dynamic factors*, but the organic chemical changes themselves which affect soil fertility must be clearly worked out. In this field of research activity much remains to be done".

While the scientific investigations named previously have been in progress, the practical experiments have been carried out during the last one year and half to obtain a desirable organic farm-yard manure, or composting on the basis of scientific information available. A brief abstract of the method will be given below and the detail description will be published later:

1. The materials used;

   Straw, weeds, garbage, street sweeping, plant residue, rice hask, *human manure*, and any other organic waste materials may be used.

2. The zymotic chamber;

   The chamber is so constructed that permits as much oxidation as possible to take place in course of fermentation. The use of thermophilic fermenter is made freely in case it is necessary.

3. The products;

   The content of the chamber is taken out after the temperature falls down and becomes constant, on average, it requires about three weeks. The compost thus produced seems to be well fermented as that produced by an ordinary method of composting which requires much longer time. The chemical composition of the product varies as the initial materials which are put into the chamber vary. An average of some samples were produced from rice straw, barley straw (fresh and

---

1) Symposium on "Soil Deterioration", J. Amer. Soc. of Agronomy, 18, 2, 1926.

2) O. SCHREINER, ibid, p. 121.

some used once on roof), rice hasks, and weeds, gave the following composition.

	Percentage.
Total nitrogen,	2.00
,, potassium,	1.44
,, phosphates,	0.85

IV. Summary and Conclusions.

1. In the field of dynamic studies of organic matter especially of cellulose in agriculture, more extensive as well as intensive research investigation should be carried out.

2. The thermodynamical study in the general microbial processes specially on the soil microorganisms should be investigated in order to obtain better knowledge of soil fertility.

3. The thermophilic cellulose fermenter seems to act vigorously on the cellulose in course of composting as well as on highly refined cellulose in culture medium.

4. A specially constructed zymotic chamber seems to aid in producing the desirable compost out of various waste materials in comparatively short time without the aid of cattle.

5. Such method of composting may be employed in a large scale as a process of disposing the waste materials in city as well as on the farm.