STUDIES IN MICROBIAL THERMOGENESIS

I. APPARATUS

ONE result of the ever-increasing demand for greater production has been a more and more incomplete "seasoning" of farm products. In many localities hays and grains are stored in a wholly uncured condition. The principal danger from this procedure lies in the "heating" which almost inevitably follows. This heating is usually accompanied by fermentation and rotting of the material, which results in a depletion of its nutritive and market values.

Most of the types of apparatus devised for the study of microbial thermogenesis have been arranged for the determination of the total number of calories of heat liberated. In an investigation concerned primarily with the maximum temperature attainable under known conditions, an apparatus furnishing the most complete insulation against radiation and the most favorable rate of gaseous exchange is desired.

In the early stages of the "spontaneous" heat production in stored organic materials[1] a considerable amount of air must be entrapped within the mass. For this reason experiments were confined to studies of the effect of aeration with oxygen. As the gases introduced will absorb heat and those escaping after the heating will remove some of the heat, it is preferable to operate with as small a gas volume as possible. For these reasons pure oxygen is used. Insulation of the mass is accomplished by packing in a commercial Dewar flask. Further insulation against radiation may be obtained by packing the flask in sawdust or powdered cork. This added precaution was found to be unnecessary for ordinary materials, however. The apparatus devised by the writer, and which has proved to be satisfactory, is shown in Fig. 1.

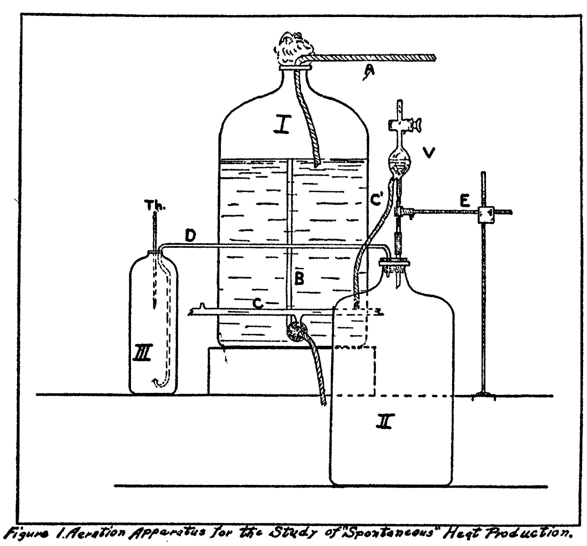

FIG. 1. Aeration apparatus for the study of "Spontaneous" Heat Production.

[1] "Organic materials" is used in this paper to denote those plant and animal substances which, when piled, produce a porous mass and which would naturally fall within the scope of this investigation.

In order to prevent corrosion, glass or brass is used in the apparatus as far as possible. The material to be studied is packed in a quart Dewar flask (III), which contains an "oxygen tube" (dotted) made from small glass tubing bent to conform to the inside wall of the flask. The lower end of the tube is turned up, with the opening in the center and near the bottom of the flask. After the material is packed in the container, a thermometer (Th) is inserted. At a favorable point in the experiment the oxygen tube is connected with the oxygen bottle (II) by glass tubing (D), connections being made through closely fitting rubber tubing. The oxygen is forced out of the oxygen bottle and into the Dewar flask by water dripping from the bevelled tip of a glass tube extending through the rubber stopper. The rate of water flow into this bottle is governed by the water head established by the valve (V). The large bottle (I) furnishes a constant level of water, (A) being the inlet and (B) the overflow. This constant head is transmitted to the valve through the manifold (C) and the rubber tubing (C′). The capillary valve (V) is held in a clamp which can be raised or lowered at will. Thus the vertical distance between the top of the water in (I) and the lower end of the capillary of the valve determine the rate of water flow from the bevelled tip leading into bottle (II).

By determining the number of drops from each tip per liter of water delivered, the volume of each drop can be calculated. At any position of the valve the rate of flow per hour can then readily be computed from the number of drops falling per minute. It is convenient to have a computing table for ready reference.

The bulb in the capillary valve surmounted by the glass stop-cock was found necessary to hold bubbles of air liberated from the cold water as its temperature rose to that of the room during its slow passage through the manifold (C) and rubber tubing (C′). This was particularly useful in winter. The oxygen bottle (II) is easily filled with oxygen by first filling with water. Absorption of the oxygen into water which collects in the bottle and the liberation of air from the water into the oxygen above can be prevented by the addition of a few cubic centimeters of paraffin oil. The effect of different gases upon the heat production can readily be determined by a simple substitution of bottles containing the desired gas.

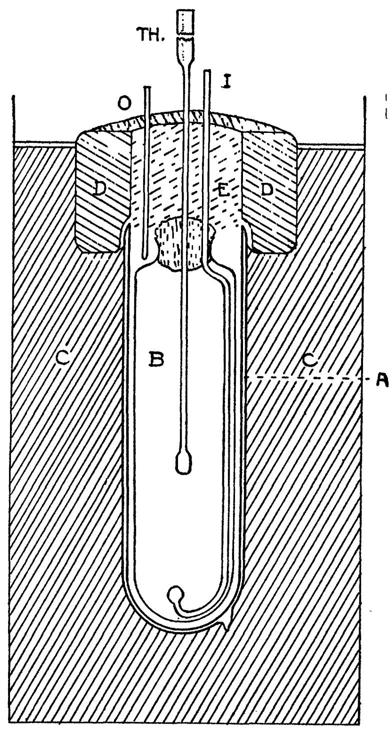

FIG. 2. Chamber for the insulation of sterilized and reinoculated materials.

Studies on sterilized and reinoculated materials can be more readily conducted if the insulating chamber of Figure 1 is substituted by one such as illustrated in Fig. 2. A wide-mouthed Dewar flask "A" (Fig. 2, a commercial vacuum food jar) is insulated in a wooden box with powdered cork "C." Two inches of magnesium-asbestos pipe covering "D" surmounts the flask in order to increase the depth of the chamber and also to place the vacuum jar well below the surface of the cork. The cylindrical hard glass receptacle "B" containing the test material is inserted into the flask and shredded asbestos fiber "E" packed into the opening above. The cylinder "B" is stoppered with cotton. The oxygen inlet tube "I" and thermometer "Th" correspond to those of Figure 1. An outlet "O" is also provided for waste gases.

PRELIMINARY EXPERIMENTS[2]

1. *Cornmeal* (*yellow commercial*). Two Dewar flasks were filled with cornmeal, the moisture content of which had been increased to about 25 per cent. No oxygen was introduced other than that incorporated during packing. The results, given in Table 1, show increases in temperature from 27.6°

TABLE 1

MOISTENED CORNMEAL PACKED IN DEWAR FLASKS AND UNAERATED

Days 1924	Time	Room Temp. °C.	Dewar No. 1 Temp. °C.	Dewar No. 1 Oxy'n cc/hr	Dewar No. 2 Temp. °C.	Dewar No. 2 Oxy'n cc/hr
0	11:00 a.m.		Packed	0	Packed	0
	2:00 p.m.	26.2	27.6		27.3	
1	9:00 a.m.	25.5	30.8		31.5	
	4:30 p.m.	26.0	31.3		32.7	
2	9:00 a.m.	23.8	30.4		32.7	
	4:30 p.m.	26.6	29.4		32.1	
3	9:00 a.m.	27.0	28.8		31.7	
	4:30 p.m.	29.5	29.1		32.1	
4	9:00 a.m.	28.0	30.1		32.6	
6			Room temp.		Room temp.	
7			Room temp.		Room temp.	

and 27.3° C. to maxima of 31.3° C. and 32.7° C., respectively, followed by decreases to room temperature again within two days. When examined, the meal appeared only slightly abnormal, being loosely caked with a small amount of mold.

Only one of many experiments performed to show the advantage of aeration with oxygen will be given.

TABLE 2

MOISTENED CORNMEAL PACKED IN DEWAR FLASKS AND AERATED WITH OXYGEN

Days 1924	Time	Room Temp. °C.	Dewar No. 9 Temp. °C.	Dewar No. 9 Oxy'n cc/hr	Dewar No. 10 Temp. °C.	Dewar No. 10 Oxy'n cc/hr
0	4:00 p.m.		Packed		Packed	
1	9:00 a.m.	26.5	28.1		26.7	
	3:00 p.m.	27.5	28.3		27.3	
2	9:00 a.m.	26.0	30.6	*144*[3]	30.6	*160*
	3:00 p.m.	27.0	33.4	108	34.5	115
	3:05			*216*		*230*
3	9:00 a.m.	25.5	42.6	29	48.3	190
	9:05			*144*		*152*
	4:30 p.m.	25.0	44.7	158	47.4	150
4	11:00 a.m.	23.0	37.9	172	42.2	216
	8:30 p.m.	25.0	45.4		53.4	
5	10:00 a.m.	25.0	50.9		52.2	
6	9:00 a.m.	24.0	48.6		52.1	
	9:30 p.m.	25.5	54.4	200	60.4	208
7	9:00 a.m.	26.5	54.3		60.8	
	3:30 p.m.	25.0	54.5		62.0	

[2] More extensive studies are in progress and will be reported later.

[3] Figures in italics indicate the number of cubic centimeters of oxygen being delivered per hour immediately following an initial setting or a readjustment of the capillary valve.

Two flasks were again packed with cornmeal of 25 per cent. moisture content and, during the heating, oxygen was supplied from the oxygen bottle. Table 2 contains data condensed from many readings taken during the seven days of the experiment. Previous experiments had indicated that beginning the oxygen aeration immediately after packing the flasks frequently resulted in no appreciable rise in the temperature. If, however, the oxygen was started after the temperature had reached some point several degrees above that of the room, in this case a temperature of approximately 30° C., continued increases always occurred. Presumably the return to room temperature of the flasks reported in Table 1 was due to the exhaustion of the oxygen in the air entrapped during packing. The rates of oxygen supply (*i.e.,* the water flow) were variable in the experiment given. This was largely due to the fact that the valves had not been properly adjusted.

The maximum temperatures contained in Table 2 are considerably above those shown in Table 1. Had the experiment been continued longer with Dewar No. 9, a maximum temperature equal to that of Dewar No. 10 might have been attained. When examined the cornmeal in the aerated flasks was moist around the top, firmly caked and browned throughout and emitted a scorched odor.

2. *Cracked Corn (yellow commercial field).* Cracked field corn is to some extent similar to cornmeal, but it is even more subject to "spontaneous" heat production. Two flasks were packed with cracked corn of approximately 33.0 per cent. moisture, one receiving oxygen and the other remaining unaerated. The results are given in Table 3. The maximum temperature attained in the aerated flask was 62.5° C. The difference between that and the temperature observed in the unaerated mass is as striking as in the previous experiments. When examined the aerated corn was damp and very moldy.

TABLE 3

Moistened Cracked Field Corn Aerated with Oxygen and Unaerated Control

			Dewar No. 3 Control		Dewar No. 4	
Days 1924	Time	Room Temp. °C.	Temp. °C.	Oxy'n cc/hr	Temp. °C.	Oxy'n cc/hr
0	2:00 p.m.		Packed		Packed	
	6:00	26.9	23.3		25.8	
1	8:30 a.m.		22.0		27.0	
2	1:30 p.m.	24.2	23.1		34.6	
	2:00					*170*[4]
3	8:00 a.m.	23.8	21.3		45.2	160
	9:00 p.m.	28.0	25.5		50.4	162
4	8:00 a.m.	27.0	27.8		54.3	145
	8:00 p.m.	27.2	28.0		55.2	*175*
	5:00	27.2	27.5		56.0	
5	8:00 a.m.	22.5			60.0	
	8:00 p.m.	31.0			61.8	156
	9:30	32.5			62.5	
6	8:00 a.m.	20.5			51.5	120

[4] See footnote, Table 2.

Summary

An apparatus for the study of the "spontaneous" heat production in stored organic materials[5] has been described. Experiments with commercial cornmeal and cracked yellow field corn have shown that temperatures above 60° C. can readily be produced under suitable conditions of moisture content, oxygen supply and insulation, and that marked heating does not take place in the absence of oxygen.

Conclusions

"Spontaneous" heat production is the result of oxidative reactions and will not take place to any marked extent in the absence of air or oxygen. Stored organic materials will not heat if retained under anaerobic conditions.

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[5] See footnote one.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE REGULAR SPRING MEETING OF THE EXECUTIVE COMMITTEE

On April 24 the regular spring meeting of the executive committee of the council of the American Association for the Advancement of Science was held at the Cosmos Club in Washington. There were three sessions, in forenoon, afternoon and evening, and the members of the committee dined together as usual. The following members were present: Cattell, Fairchild, Humphreys, Kellogg, Livingston, A. A. Noyes, W. A. Noyes, Ward, and Wilson. Those absent were Moulton and Pupin. The following paragraphs give an account of the business transacted.

1. The reading of the minutes of the last meeting was omitted, since, as usual, these had been approved by mail.

2. The permanent secretary reported that all mem-