CCXIII. THE PRODUCTION OF MUCUS DURING THE DECOMPOSITION OF PLANT MATERIALS[1].

I. THE EFFECT OF ENVIRONMENTAL CONDITIONS.

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It has been observed that the straw in some manure heaps undergoing decomposition develops stickiness. Such sticky manures may be better adapted to light sandy soils and are possibly unsuitable for heavy clays. The possible effect of mucilage from plant residues on the physical behaviour of the soil has been suggested by Hutchinson and Clayton [1919]. The substance conferring on manures the physical property of stickiness will be referred to hereafter as mucus. It is apparent that mucus formation must be a result of the microbiological activity during decomposition.

Though the decomposition of plant materials has been studied extensively and the losses of individual constituents followed in detail by Rege [1927], Waksman [1928] and Norman [1929], no reference is made in the literature to the production of mucus.

The experiments described in this paper were designed to examine the conditions involved in the production of mucus. Straw was fermented in the presence of different sources of available nitrogen with changes in the physical conditions and reaction: Extractions of the decomposed straws were made to seek any possible correlation between the rates of their decomposition and the production of mucus. The amount of mucus produced was measured by a specially devised physical test.

Physical test for measuring the stickiness.

The principle of the method consists in measuring the vertical force required to separate after drying two metal plates which contain between them a known weight of the manure sample.

The following apparatus is required for the determination—a number of pairs of metal plates, one of 4 ins. square and the other of 3 ins. square with a hook in the centre, a system of two frictionless pulleys in a horizontal plane, lead shot, a receptacle to receive the lead shot and a lead weight weighing 1600 g. with a slit to fit over the hook of this plate. This apparatus is represented diagrammatically in Fig. 1.

The metal plates should be sufficiently rigid not to bend under the forces applied. In order to keep the lower plate firmly fixed, while the force is being

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applied, it is made to slide in between two jaws made by screwing to the bench top two metal pieces over another of 4 ins. length and of the same thickness as that of the plates. The lower two plates are kept parallel and 4 ins. apart in such a way that the lower metal plates of 4 ins. square can be easily slid in with no danger of causing any jerks to the plates containing the manure. When the plates are ready for measuring the pull, the lower plate is gently slid in, the loop at one end of the string over the pulleys is put in the hook of the top plate and

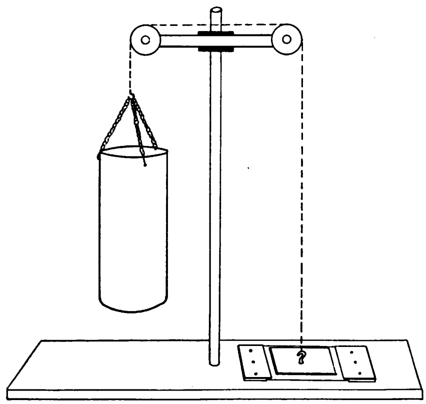

Fig. 1. Apparatus used for measuring stickiness.

the other is connected with the receptacle for carrying the lead shots. The shots are gradually poured in till the top plate is vertically lifted instantaneously from its position of rest. The weight of the shots *minus* the weight of the top plate gives the total pull to separate the two plates. The diameter of the circular block occupied by the manure is measured. An average of three or four readings in different positions is taken as the block is not usually regular. Knowing the diameter and the pull recorded, the force per unit area can be calculated.

The procedure consists in cutting the rotted straw as finely as possible, after which the mass is thoroughly mixed and vigorously worked with a spatula to obtain an even mixture. One gram portions are then weighed out on each of the plates. The mass is gathered into a mound by the spatula in the centre of the plate and the top plate placed in such a way that it rests freely with faces parallel. It is then pressed with the lead weight for 15 seconds and dried at 100° in an oven overnight to ensure uniform and complete drying. It is essential in all the experiments to keep constant the weight and time for pressing the plates, because the area of the manure and its height or thickness depend upon the force with which the top plate is pressed against the manure surface, whilst the pull required to separate the two plates depends upon the distance between them and therefore upon the thickness of the manure disc. In his early experiments on the stickiness of soils Kachinski [1930] left a weight on the sample for a specified time. Bouyoucos [1932] however pressed the plates with the hands, introducing different pressures at different times, without considering the thickness of the disc occupied by the soil.

Table I gives the significance of the determinations of stickiness made by the physical test. It will be seen that the magnitude of the error increases inversely with stickiness and that with highly sticky and moderately sticky samples the figures for stickiness are significant.

Table I. *Significance of the determinations of stickiness made by the physical test.*

Readings	Actual pull recorded in g.	Radius of the manure disc in cm.	Force per unit area per 1 g. of wet sample	Force per unit area per 1 g. of dry sample
	$NaNO_3$ rot: dry matter 13 %. Very sticky.			
1	5200	1·25	1059	8140
2	4875	1·25	991	7620
3	4958	1·25	1010	7770
4	4800	1·20	1061	8160
5	4110	1·25	837	6436
6	5190	1·25	1056	8120
7	5000	1·25	1018	7830
	5075	1·25	1034	7944
		Mean		7752·5
		Standard deviation		566·32
		Standard error of the mean		± 200·2
	Urea rot: dry matter 20 %. Moderately sticky.			
1	2000	1·30	481·4	2407
2	1800	1·25	366·4	1832
3	1200	1·25	244·5	1222
4	1600	1·20	353·7	1768
5	1900	1·20	420·1	2100
6	2000	1·25	407·3	2036
7	2050	1·25	417·4	2087
8	1800	1·20	390·0	1990
		Mean		1930·2
		Standard deviation		345·0
		Standard error of the mean		±121·9
	$(NH_4)_2CO_3$ rot: dry matter 12 %. Slightly sticky.			
1	130	1·80	12·7	105·8
2	150	1·75	13·5	101·2
3	100	1·40	16·2	135·3
4	150	1·70	16·5	137·7
5	290	1·60	36·0	300·5
6	100	1·60	12·4	103·5
7	250	1·50	35·3	294·1
8	220	1·60	27·3	227·5
		Mean		175·7
		Standard deviation		85·4
		Standard error of the mean		±30·2

EXPERIMENTAL.

The physical test for stickiness was carried out on decomposed straws obtained under the various conditions outlined below.

Oat straw was rotted in presence of mixed flora for 30 days with the following changes in the environmental conditions.

(*a*) Variation in the initial moisture content at 35°.

(*b*) Variation in the sources of nitrogen at 35°.

(*c*) Variation in temperature—15°, 25°, 35° and 45°—with urea as the source of nitrogen.

(*d*) Variation in temperature—15°, 25°, 35° and 45°—with sodium nitrate as the source of nitrogen.

(*e*) Degree of decomposition at 35° with sodium nitrate as the source of nitrogen.

(*f*) Adjustment of p_H at 10·0 independent of the source of nitrogen.

Technique and methods.

Twenty g. of air-dry chaffed oat straw of known moisture and nitrogen contents were fermented aerobically in bottles with its natural mixed flora. Nitrogen was supplied to the extent of 1 g. per 100 g. of straw and the bottles incubated at the desired temperature. They were turned round in the first few days to ensure thorough wetting and frequently stirred to get homogeneous distribution of nitrogen and moisture. Water-logging was avoided as it causes anaerobic conditions. After the desired period each bottle was weighed with its contents and analysed as indicated below.

1. Extractions with water, 1 % sodium carbonate and 1 % sodium hydroxide. In each case 10 g. of the wet sample were boiled for 5 minutes with 100 cc. of water and filtered. The aqueous extract was evaporated to dryness on a water-bath and weighed. The alkaline extracts were precipitated with a few drops of hydrochloric acid, gently heated to coagulate the precipitate and then filtered through tared papers. The precipitates were well washed, dried and weighed.

2. Extractions with 90 % alcohol were carried out in a Soxhlet apparatus for 6 hours. Upon removal of the alcohol the extract was weighed, and after hydrolysis by boiling with 5 % H_2SO_4 for 2 hours its sugar content was determined by the Mohr-Bertrand method.

3. Treatment with hydrogen peroxide: the method employed was described by Shrikhande [1933].

4. Ammonia-N was determined by distillation with MgO.

5. Nitrate-N on the samples rotted with sodium nitrate was determined by distillation of the residue from ammonia-N in presence of alkali and Devarda's alloy.

6. Total N was determined by the usual Kjeldahl method. In the presence of nitrate-N the sulphuric-salicylic acid method was adopted.

Results.

Series (*a*) *and* (*b*). Fungi were noticed on or about the 6th day. At the end of 30 days no trace of fungus mycelium was obvious except with ammonium carbonate and urea. *Coprinus* seemed to be very active in ammonium carbonate, urea and sodium nitrate rots. Better decomposition was observed with ammonium sulphate when calcium carbonate was introduced. Fungus growth was hardly noticeable at 15°. The rots appeared different under different conditions. The manures obtained, using ammonium carbonate, sodium nitrate and mould tissues as the source of nitrogen at high moisture contents, were noticeably slimy.

Effect of initial moisture content.

Table II gives the effect of initial moisture content upon the decomposition and nitrogen transformation. In each case the moisture content initially was adjusted at 60, 70, 80 and 90 %. During the course of decomposition an attempt was made to maintain the above levels of moisture but at the end of 30 days they seem to narrow down to about 85 to 98 %, which seems to be the optimum moisture necessary for pronounced rotting.

The series with ammonium carbonate, ammonium sulphate and sodium nitrate were repeated twice. Series (*a*) was used for nitrogen determinations and series (*b*) for extractions and the physical test for stickiness. The figures for moisture content and the losses of dry matter indicate that the higher the moisture content the greater the activity of the organisms and consequently the greater is the degree of decomposition. This observation agrees with that of Engberding [1909] who found an increased number of bacteria with the increased

Table II. *Nitrogen content of straws rotted by mixed floras with different sources of available nitrogen for 30 days at 35°.*

Expressed on 100 g. dry straw.

Initial moisture %	Dry matter	Loss of D.M.	NH_3-N	NO_3-N	Total N	N factor	N equiv.
			Ammonium carbonate.				
60	(*a*) 13·8	39·6	0·018	0·0	1·20	0·89	2·2
	(*b*) 19·7	36·5					
70	(*a*) 12·8	40·6	0·016	—	1·33	0·96	2·3
	(*b*) 15·0	39·2					
80	(*a*) 12·0	41·2	0·013	—	1·33	1·06	2·5
	(*b*) 14·0	45·0					
90	(*a*) 11·9	42·2	0·044	—	1·71	1·20	2·8
	(*b*) 11·4	44·4					
			Ammonium sulphate.				
60	(*a*) 17·0	36·5	0·467	—	1·29	0·68	1·8
	(*b*) 23·4	30·1					
70	(*a*) 15·9	28·5	0·595	—	1·49	0·59	2·1
	(*b*) 19·3	32·5					
80	(*a*) 15·4	23·4	0·550	—	1·41	0·69	3·0
	(*b*) 16·7	31·5					
90	(*a*) 14·0	20·0	0·593	—	1·68	0·68	3·4
	(*b*) 14·7	30·7					
			Sodium nitrate.				
60	13·8	30·7	0·041	0·119	1·76	0·83	2·7
70	(*a*) 13·6	49·2	0·012	0·020	1·18	0·81	1·6
	(*b*) 15·2	52·8					
80	(*a*) 13·4	43·7	0·009	0·009	1·20	0·63	1·4
	(*b*) 13·3	52·3					
90	12·6	48·7	0·027	0·027	1·31	0·89	1·8
			Water.				
80	18·2	30·0	—	—	0·36	0·16	5·3
			Peptone.				
75	16·5	39·5	0·004	—	1·48	1·12	2·8
75	15·6	44·1	0·007	—	1·49	1·10	2·4
			Caseinogen.				
75	17·0	43·0	0·002	—	1·46	1·10	2·5
75	17·1	41·8	0·002	—	1·30	1·07	2·5
			Urea.				
75	20·0	32·5	0·003	—	1·36	1·03	3·1
75	18·9	34·0	0·004	—	1·67	1·30	3·8

moisture content of the soil. There is, however, an exception to this in the case of ammonium sulphate where the order is reversed. It is possible therefore that a high moisture content with $(NH_4)_2SO_4$ as the source of nitrogen depresses the activity of the organisms.

The figures for "nitrogen factor" of straws rotted at 35° were determined for the sake of comparison and are given in column 7 of Table II. The nitrogen factor in these cases is the resultant of the many organisms involved and shows a tendency to increase with higher moisture content, meaning that it increases with the degree of decomposition for the particular source of nitrogen. Ammonium sulphate gives the lowest nitrogen factor whereas ammonium carbonate gives the highest with inorganic sources of nitrogen. Sodium nitrate however does not appear so good as ammonium carbonate from the point of view of nitrogen immobilisation although it gives a higher decomposition. The nitrogen factor with organic sources of nitrogen is of little value because it is difficult to distinguish between nitrogen synthesised by the organisms and the organic nitrogen supplied.

"Nitrogen equivalents" are given in Table II, column 8. Sodium nitrate gives the lowest figure of 1·4 with 80 % initial moisture content indicating the greatest activity of the organisms per g. of N. The highest figure is 3·4 with $(NH_4)_2SO_4$ and 80 % moisture, no doubt due to the low activity of the organisms in this case.

Hutchinson and Clayton [1919], while discussing the decomposition of cellulose with *Spirochaete cytophaga*, say "from the chemical standpoint and on account of its insolubility in acids and solubility in ammonium hydroxide, the mucilage would without doubt appear in the 'crude humus' fraction in the conventional soil analysis." An attempt was made to extract this fraction possibly responsible for the stickiness. Table III gives the figures for various extracts and the values for the stickiness as measured by the physical test. The figures for stickiness were obtained on the mixture of samples with the different moisture contents for a particular source of nitrogen. The maximum stickiness was obtained with sodium nitrate, which also gave the greatest decomposition and the highest water, sodium carbonate and sodium hydroxide extracts. Mould tissue is the source of nitrogen which gives the maximum decomposition. 2 % nitrogen supplied as tissue gives extracts of the same order as sodium nitrate though the stickiness is rather lower. Double the amount of tissue produces more than double the amount of stickiness. This clearly indicates that stickiness depends a great deal upon the quantity of elaborated fungal tissue. The lowest figures for stickiness and extracts were obtained with ammonium sulphate. The best correlation between stickiness and extracts seems to be obtained with sodium carbonate extraction. This is expressed graphically in Fig. 2. The

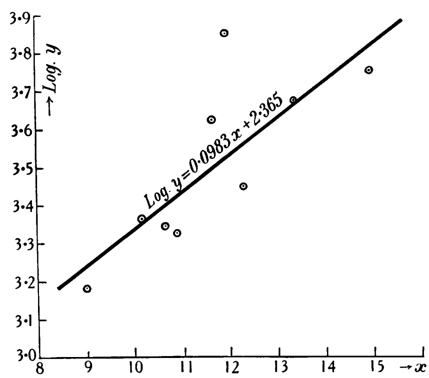

Fig. 2. Correlation between stickiness and sodium carbonate extracts of manures.

logarithm of stickiness when plotted against the extract can approximately be represented by a straight line. Log $y = 0{\cdot}0983x + 2{\cdot}365$.

The aqueous extract increases with the degree of decomposition. Water would extract some protein, very little of the hemicelluloses and any water-soluble material, gummy or otherwise, synthesised during decomposition. The larger water extract can therefore be explained by the presence of more of the

Table III. *Different extracts with physical test for stickiness and* p_H *values of straws rotted by mixed flora with different sources of nitrogen for 30 days at 35°.*

Expressed on 100 g. dry manure.

Initial moisture %	Loss of D.M.	Alcoholic extract	Sugars in alcoholic extract mg.	H_2O extract	NaOH extract	Na_2CO_3 extract	Physical test g.	Initial p_H	Final p_H	H_2O_2 extract
					$(NH_4)_2CO_3$.					
60	(*a*) 37·16	5·16	1139·5	—	—	—				
	(*b*) 36·50	6·20	—	21·1	16·9	11·5				
70	(*a*) 40·60	5·04	326·9	—	—	—				
	(*b*) 39·20	8·50	—	21·2	18·2	11·9	4241	9·0	8·0	20·2
80	(*a*) 41·20	4·30	462·5	—	—	—				
	(*b*) 45·00	5·20	—	22·2	11·4	8·8				
90	(*a*) 42·20	4·58	382·2	—	—	—				
	(*b*) 44·40	10·30	—	29·3	13·5	3·5				
					$(NH_4)_2SO_4$.					
60	(*a*) 36·50	4·19	418·0	—	—	—				
	(*b*) 30·10	9·00	—	17·9	16·8	7·7				
70	(*a*) 38·50	4·45	529·0	—	—	—				
	(*b*) 32·50	8·20	—	20·5	13·3	4·1	220	5·5	6·5	14·5
80	(*a*) 23·40	4·50	520·0	—	—	—				
	(*b*) 31·50	9·20	—	20·8	14·4	3·3				
90	(*a*) 20·0	5·30	513·0	—	—	—				
	(*b*) 30·7	9·30	—	19·8	12·2	4·5				
					$NaNO_3$.					
60	30·7	5·50	247·6	—	—	—				
70	(*a*) 49·2	3·80	104·8	—	—	—				
	(*b*) 52·8	9·10	—	44·3	17·4	15·5	7164	6·35	10·0	27·4
80	(*a*) 43·7	4·30	109·8	—	—	—				
	(*b*) 52·3	10·30	—	62·1	19·3	8·3				
90	48·7	4·35	182·0	—	—	—				
					Water.					
80	30·0	6·35	—	12·9	10·5	1·2	0	5·50	—	16·3
					Peptone.					
75	39·5	8·25	—	21·5	15·2	10·9	1504	5·75	7·5	16·3
75	44·1	7·11	—	26·9	16·6	7·2				
					Caseinogen.					
75	43·0	7·10	—	28·7	24·5	11·9	2727	—	7·5	15·8
75	41·8	11·05	—	27·2	19·4	13·5				
					Urea.					
75	32·5	8·36	—	25·3	19·7	11·6	2278	6·45	7·5	12·8
75	34·0	10·04	—	19·0	8·7	8·7				
					$(NH_4)_2SO_4+CaCO_3$.					
80	35·9	—	—	—	—	10·6	2176	—	7·5	—
					$Ca(CN)_2$.					
80	29·1	—	—	—	—	13·2	4635	—	—	—
					Mould tissue to give 1 % nitrogen.					
80	57·7	—	—	28·4	10·3	17·9	2124	—	8·2	—
					Mould tissue to give 2 % nitrogen.					
80	61·6	—	—	36·9	10·0	20·3	5622	—	8·2	—

protein and other microbial constituents which are progressively synthesised and possibly also of more gummy material which seems to increase, as indicated by the high stickiness with the physical test.

The alkaline extracts diminish with the time of decomposition. Alkaline treatment extracts more than water alone, but only a part of the substances in solution is precipitated by acid. The materials extracted with alkali are practically of a similar nature to those obtained with hot water. Extraction may vary with increasing concentration and nature of the alkali. 1 % sodium hydroxide would extract lignin to an appreciable extent, and on comparing the figures for sodium hydroxide and sodium carbonate extracts it is seen that the sodium hydroxide extract is nearly one and a half times the sodium carbonate extract. The weight of the extracts increases as the stickiness increases.

Of organic solvents only alcohol was found to extract a certain fraction of manure and the humus from it. Alcoholic extracts are practically of the same order in each case. There is a tendency for the extract to increase with the degree of decomposition. The sugar content or the extract from ammonium carbonate on an average is greater than that from ammonium sulphate or sodium nitrate.

The significance of extraction with hydrogen peroxide is discussed in detail elsewhere [Shrikhande, 1933]. Much importance cannot be attached to the relationship between peroxide extract and stickiness. The nature of this extraction differs from others in the sense that this solvent oxidises some of the decomposed and synthesised material. All extracts if plotted graphically against stickiness give a straight line. In the rots with caseinogen there is an exception to the general order as mentioned above, all the extracts being disproportionately greater. This may be due to the fact that less caseinogen is decomposed by the organisms, and the remainder is dissolved by the solvents and returned unchanged in precipitates.

The initial p_H was highest with ammonium carbonate and lowest with ammonium sulphate. Sodium nitrate which was practically neutral at the start gave a final p_H of 10·0. The highest stickiness and decomposition were obtained with sodium nitrate and correspondingly lowest figures with ammonium sulphate, which maintained an acid reaction throughout. When, however, an equivalent amount of calcium carbonate was supplied to the ammonium sulphate rot, decomposition increased with an increase in stickiness. This leads to the conclusion that maximum stickiness is associated with alkaline conditions. This may mean either that the organisms responsible for stickiness are favoured by an alkaline medium, that there is a modification of the flora with the change in the environmental conditions or that the manifestation of the property of stickiness is enhanced by alkaline conditions. The p_H with all the three organic sources of nitrogen is practically of the same order (7·5) and similar figures for stickiness were obtained. The final high p_H with sodium nitrate is no doubt due to the utilisation of nitrate-N leaving excess of base. The slight lowering of p_H with ammonium carbonate may be ascribed to the use of nitrogen from ammonia and the liberation of CO_2.

Table IV. *Different extracts with physical test for stickiness and final* p_H *values of straws rotted by mixed floras with available nitrogen as urea and* $NaNO_3$ *at different temperatures.*

Expressed on 100 g. dry manure.

Temp. °C.	Source of N	Loss of D.M.	Physical test (g.)	Final p_H	Water extract	Na_2CO_3 extract	NaOH extract
15	Urea	7·2	414	7·8	17·1	7·7	13·2
	$NaNO_3$	12·3	2610	9·0	23·2	5·2	10·5
25	Urea	40·6	5020	8·0	29·6	11·9	16·0
	$NaNO_3$	30·2	3678	9·5	31·8	8·5	17·5
35	Urea	33·0	2278	7·5	25·3	11·6	19·7
	$NaNO_3$	52·5	7164	10·0	44·3	15·5	19·3
45	Urea	58·2	3650	8·5	38·7	18·1	19·8
	$NaNO_3$	40·9	7875	10·0	47·5	18·4	22·3

Series (*c*) *and* (*d*). *Variation in temperature with urea and sodium nitrate as sources of nitrogen.* Table IV contains results of extraction, final p_H and stickiness on samples of straws obtained as indicated above.

The losses of dry matter seem to increase with the increase in temperature. At 15° the decomposition is very poor in both cases, though sodium nitrate gives double that of urea. The decomposition obtained with urea at 25° is more than that at 35°. At 45° urea gives a decomposition of 58 %, which is much more than with sodium nitrate. These variations clearly indicate the different nature of the flora working at the different temperatures. The final p_H for urea varies between 7·8 at 15° and 8·5 at 45°. Similarly the p_H with sodium nitrate has increased from 9·0 at 15° to 10·0 at 45°. The initial p_H values were 6·45 and 6·35 respectively.

Stickiness. Even with a very small decomposition sodium nitrate produces quite an appreciable amount of stickiness, which increases with the rise in temperature. The maximum stickiness with urea as a source of nitrogen is produced at 25°.

Series (*e*). *Degree of decomposition at 35° with sodium nitrate as the source of nitrogen.* Table V indicates the relationship observed between the stickiness of the manure and the degree of decomposition when sodium nitrate was supplied

Table V. *Effect on the production of stickiness of modification of the* p_H *and the degree of decomposition.*

Source of N	Time in days	Loss of D.M. %	Physical test in g. On manure	On original straw	Final p_H	p_H adjusted To	With	On manure
$NaNO_3$	8	4·7	2050	1954	8·0	9·5	Na_2CO_3	3868
„	16	23·1	4020	3903	9·0	9·5	Na_2CO_3	5521
						9·5	K_2CO_3	5123
						8·0	H_2SO_4	3648
						5·5	H_2SO_4	2305
„	24	32·2	7834	5310	9·5	—	—	—
„	32	34·8	8161	5320	9·5	8·0	H_2SO_4	5991
						7·0	H_2SO_4	4538
						5·5	H_2SO_4	3410

as the source of nitrogen. The physical test increases markedly as decomposition proceeds. There was, however, a possibility that this might be an effect of the changing reaction of the rot, which becomes progressively more alkaline and reaches finally a p_H of 9·5. To investigate this point the samples after 8 and 16 days' decomposition were adjusted to the final p_H of 9·5 by addition of sodium carbonate. This had the effect of increasing the figures for the physical test very appreciably, but not so much that they approached the level obtained at this p_H with longer periods of decomposition. There is therefore a direct relationship between the degree of decomposition of a manure and its stickiness, even when all the changes in the reaction have been taken into account. This point is more clearly brought out when the physical test is recalculated on a basis of original straw. The stickiness increased till the 24th day, after which further loss of organic matter was not accompanied by further production of apparent sticky material.

Further to demonstrate the effect of reaction, samples rotted for 32 days, having achieved the very high degree of stickiness indicated by a physical test of 8161 g., were acidified and the p_H reduced to 8·0, 7·0 and 5·5. This had the effect of lowering the stickiness to 5970 g., 4538 g. and 3410 g. respectively. Similar adjustments of the p_H with sodium carbonate, potassium carbonate and sulphuric acid were made with the sample rotted for 16 days. These experiments indicate that the stickiness varies directly with the p_H within the limits tested. The relation between stickiness and reaction is represented graphically in Fig. 3.

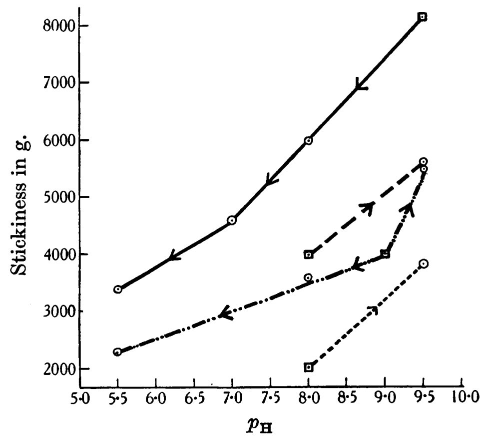

Fig. 3. Relationship between stickiness and reaction.

⊡ Initial point.	→ Changes due to alteration in p_H.
——— $NaNO_3$ 30 days.	— — Urea 30 days.
—··— $NaNO_3$ 16 days.	- - - - $NaNO_3$ 8 days.

Series (f). Adjustment of p_H *at 10·0 independently of the source of nitrogen.* Table VI deals with the effect on stickiness of the initial reaction of the material undergoing decomposition. Various sources of nitrogen were supplied and the

Table VI. *Effect of the initial* p_H *on the production of stickiness.*

Source of N	Initial p_H brought to 10·0 with	Final p_H	Loss of D.M. %	Physical test g.
Peptone	$MgCO_3$	8·0	35·3	3938
Peptone	Na_2CO_3	8·5	49·0	6490
Mould tissue as 1 % N	$MgCO_3$	8·0	37·0	4789
*Mould tissue as 1 % N	Na_2CO_3	8·0	52·2	4114
Mould tissue as 2 % N	$MgCO_3$	8·0	50·3	4863
Mould tissue as 2 % N	Na_2CO_3	8·5	56·5	5349
Urea	$CaCO_3$† (p_H: 9·0)	8·0	39·0	3991
Urea	Na_2CO_3	8·5	42·3	6001

* Water-logged. † Final p_H brought to 10·0 by adding Na_2CO_3. Stickiness then equals 5620 g.

initial p_H of the straw adjusted to 10·0 with magnesium carbonate in one series and sodium carbonate in another. This particular reaction was chosen because the highest figure hitherto obtained for stickiness was found in a rot supplied with sodium nitrate which had attained finally that high degree of alkalinity. During fermentation the p_H values of both the series fell somewhat, those with magnesium carbonate more than those with sodium carbonate. The losses of dry matter and stickiness obtained were however invariably greater in the latter series. It is clear that if rots are adjusted initially to a high degree of alkalinity the manure resulting is stickier than that which is usually obtained. Furthermore it appears that, given the correct p_H, sodium or potassium ions are more favourable than are calcium and magnesium.

The effect of sticky manure on soils.

Three soils of different composition were selected, a Rothamsted soil which owing to a high clay content is very heavy, a Woburn and a Cheshire soil, both of which are light, but the former more sandy. Two grams of the soil sample were mixed as uniformly as possible with one gram of the sticky manure and made into a paste with water. The dry matter of the mixed sample was adjusted to about 50 %. The physical test was carried out on one gram of this mixture as in the case of manures. Stickiness of the soils when wet and after drying was also determined to compare with the figures after mixing them with the sticky manure. The following table contains these figures.

	Physical test in g.		
Soil	Wet	Dried	When mixed with manure and dried
Rothamsted	431	924	947
Cheshire	0	424	829
Woburn	0	214	686

There is therefore a definite increase in the stickiness of light soils on mixing with such a manure.

The nature of the mucus.

Attempts to extract the sticky constituents of the manure with different solvents give unsatisfactory results. The usual method of precipitating gums from water and mildly alkaline extracts with absolute alcohol and Fehling's solution was also tried without success.

A sodium nitrate rot with mixed flora, which was definitely sticky to the touch and markedly so by the physical test, was extracted with cold water. The extract was colloidal. It was filtered twice through glass wool and finally through a filter-paper under suction. The extract was then precipitated with a few drops of HCl. The precipitate was coagulated by gentle heating on a hot plate and then filtered on a Büchner funnel. A very small fraction of this mixed with 1 g. of dry oat straw proved to be quite sticky. On drying the precipitate became very hard and gritty and lost its binding properties in part. Having thus established that the above precipitate contains a sticky constituent both when wet and dry, the following analytical figures are obtained on the extract.

Water extract	9·86 % on dry matter
Physical test for stickiness with 1 g. of the wet manure	4880 g.
Physical test with the wet extract ...	2555 g.
Physical test with the extract dried and then re-moistened	1575 g.
On hydrolysis with 3 % H_2SO_4 for 5 hours	
Apparent anhydroglucose	52·04 %
Anhydropectose	2·46 %
Protein	21·50 %
Ash	3·20 %
Total	79·20 %

After acid hydrolysis the extract reduced Fehling's solution and gave Selivanoff's test for fructose. On oxidation of a portion with concentrated nitric acid a precipitate was obtained consisting of colourless plates and micro-sandy crystals. The crystals were separated by shaking up with hot alcohol in which the plates dissolved. The insoluble residue had M.P. over 200°, and when distilled with conc. HCl yielded furfuraldehyde indicating the presence of mucic acid.

The extract appears therefore to be a mixture of carbohydrates and proteins, and no doubt in part consists of material extracted from the elaborated microbial tissue. The carbohydrate portion of the extract seems to consist largely of galactan, though indications have been obtained also of the presence of uronic acids and a little pentose.

SUMMARY.

1. The conditions under which stickiness is produced in decomposing plant materials and manures have been investigated and some information obtained as to the nature of the substances contributing this property.

2. A physical test for evaluating the property of stickiness in manures has been described.

3. In the presence of a mixed natural flora, the chief factors involved in causing stickiness in decomposing straw are the source of nitrogen supplied, the initial and final reactions of the material and the degree of decomposition.

4. High values for stickiness are given with either sodium nitrate or mould tissues as the sources of nitrogen. This suggests that an alkaline reaction and an abundance of microbial tissue are essential in the production of stickiness during decomposition by mixed flora.

5. The final reaction of the manure profoundly influences the degree of stickiness, if at all appreciable. A p_H of 9·5 to 10·0, whether obtained by fermentation or by subsequent adjustment, seems to give the maximum stickiness. Sodium or potassium ions produce more stickiness than calcium or magnesium.

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