

LOSSES IN MAKING AND STORING FARMYARD MANURE.

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THE objects of the investigation described in this and the following pages are two: to determine the losses in constituents of manurial value which take place in the process of making and storing farmyard manure in the ordinary course of good farming practice, and to determine the proportion of the constituents of manurial value of such purchased foods as "cakes" which actually find their way on to the land.

With these objects in view, four heifers were fed for a period of 84 days on carefully weighed and analysed diets, and at the end of the experiment the dung was weighed and analysed. From the figures so obtained, the amounts of nitrogen, phosphoric acid, and potash in the foods eaten, can be calculated, and compared with the amounts recovered in the dung.

The actual details of the experiment are as follows:

The experimental feeding began on 31 January 1906, and ended on 25 April 1906, a period of 84 days. During this time two of the animals consumed 13720 lbs. of mangels, 1176 lbs. of hay, and used up 1963 lbs. of straw as food and litter. The other two animals in the adjoining box consumed almost exactly the same amounts of mangels, hay, and straw, and in addition 672 lbs. of decorticated cotton cake.

Samples of all the foods and litter were set apart from time to time during the experiment. At the end of the time these were chaffed, pulped, or ground, as seemed best to meet the case, and small samples drawn for analysis.

The live-weight of the animals was ascertained at the beginning and end of the experiment, and from the live-weight increase, the weights of nitrogen, phosphoric acid, and potash retained in the bodies of the animals were calculated, on the assumption that these amounts would

be the same proportion of the increase in both cases, namely that given by Lawes and Gilbert for young growing animals¹. This assumption is probably not quite accurate, since the increase in the case of the better fed animals might be expected to contain a greater proportion of fat, and consequently a smaller proportion of manurial constituents.

On 22 May 1906 the dung was sampled. At this time it was in a solid well trodden down condition, just as the animals had left it. The sampling was carried out without disturbing the dung, by cutting out a number of blocks with a hay-knife. These were well mixed, a small sample taken for analysis, and the rest replaced and trodden down. Duplicate samples were taken in this way from each box. The second sampling took place on 6 November 1906, about six months after the first. This time the samples were taken by throwing occasional forkfuls into a barrow, when the dung was being carted out of the boxes on to the land. On this occasion it was also weighed.

The weight of the dung on 22 May was calculated from the analyses, on the assumption that no loss of phosphoric acid had taken place between the two dates of sampling². It was considered that this procedure would introduce fewer errors than the disturbance of the dung which would have been entailed in weighing it on the first occasion of sampling.

The analysis of the dung was carried out as follows:—2500 grams were dried by spreading out on a large enamelled iron tray which was kept on a hot plate at about 60° C. in a good draught. The drying was completed in the steam-oven. The dried dung was chaffed, and finally ground in a mill. Nitrogen was estimated in the dry-matter by Kjeldahl's method, phosphoric acid and potash in the ash of the dry matter, the latter by Laurence Smith's method. Nitrogen in the form of ammonia was estimated in the fresh dung by shaking 500 grams with 1000 c.cm. of approximately decinormal hydrochloric acid. The liquid was strained off through cloth, its total volume calculated by adding to 1000 c.cm. the volume of water contained in 500 grams of dung, as found in the dry-matter estimation, and an aliquot part distilled with magnesia into standard acid.

The boxes in which the animals were housed during the experiment were bricked up to the highest level reached by the dung. Their floors were not cemented, but were made of clay which was well rammed, and through which there could be little leakage of soluble constituents.

The following table gives the figures :

¹ *J. R. A. S. E.*, 3, viii. 702.

² *Cp. Dyer, J. Agr. Sc.* 1. i. 111.

NO CAKE										CAKE FED								
Percentage composition					Containing by weight, lbs.					Weight, lbs.	Percentage composition				Containing by weight, lbs.			
Dry matter	Nitro- gen	Phos- phoric acid	Pot- ash	Dry matter	Nitro- gen	Phos- phoric acid	Pot- ash	Dry matter	Nitro- gen		Phos- phoric acid	Pot- ash						
13720	13.0	0.128	0.047	0.366	1784	17.6	6.4	50.2	13720	13.0	0.128	0.047	0.366	1784	17.6	6.4	50.2	
1176	84.0	1.810	0.410	2.25	988	21.3	4.8	26.5	1176	84.0	1.810	0.410	2.25	988	21.3	4.8	26.5	
1963	84.0	0.460	0.070	1.810	1649	9.0	1.4	35.5	1863	84.0	0.460	0.070	1.810	1565	8.6	1.3	33.7	
...	...	...	...	...	...	...	...	...	672	90.0	6.37	3.18	2.40	605	42.8	21.4	16.1
...	...	...	...	...	4421	47.9	12.6	112.2	...	...	...	...	...	4942	90.3	33.9	126.5
152	75.4	2.54	1.72	0.22	115	3.8	2.6	0.4	326	75.4	2.54	1.72	0.22	246	8.2	5.6	0.8	
...	...	...	...	...	4306	44.1	10.0	111.8	...	...	...	...	...	4706	82.1	28.3	125.7
11333	22.85	.318	.075	.855	2590	36.0	8.5	96.9	12370	24.1	.574	.190	+	2969	71.0	23.5	—	
...	...	...	...	...	1716	8.1	1.5	14.9	...	...	...	...	...	1737	11.1	4.8	5.1
...	...	...	...	...	2.6	8.0	20.6	0.4	...	...	...	...	...	5.0	9.0	16.4	0.6
...	...	...	...	...	58.6	75.2	67.5	86.4	...	...	...	...	...	60.0	78.5	69.3	—
...	...	...	...	...	38.8	16.8	11.9	13.2	...	...	...	...	...	35.0	12.5	14.3	—
8075	23.2	.383	.105	1.01	1873	30.9	8.5	81.6	8106	25.3	.576	.290	1.11	2051	46.7	23.5	90.0	
...	...	...	...	...	717	5.1	0.0	15.3	...	...	...	...	...	918	24.3	0.0	30.6
...	...	...	...	...	16.2	10.6	0.0	13.6	...	...	...	...	...	18.6	26.9	0.0	24.2
...	...	...	...	...	55.0	27.4	11.9	26.8	...	...	...	...	...	53.6	39.4	14.3	28.3
...	...	...	...	...	42.4	64.6	67.5	72.8	...	...	...	...	...	41.6	51.6	69.3	71.1

* Figures for growing animals. *J. R. A. S. E.* 1897, 3, viii. 701.

+ A mistake was found in this estimation, and the sample had unfortunately been destroyed before the analysis could be repeated.

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The losses which occur in making farmyard manure.

The following figures abstracted from the large table give information on this point :

Dung made by	Amounts not recovered in dung or in increased live-weight per 100 parts consumed in food and litter			
	Dry matter	Nitrogen	Phosphoric acid	Potash
Animals eating roots and hay only...	38·8	16·8	11·9	13·2
Animals eating roots, hay, and cake .	35·0	12·5	14·3	—
Average loss.....	36·9	14·6	13·1	13·4
Estimated in increased live-weight ...	...	8·5	18·5	0·5
Recovered in dung .....	...	76·9	68·4	86·1

The duplicates agree on the whole very satisfactorily, and the figures shew that it is possible in ordinary good farming practice to recover in the fresh dung about $\frac{3}{4}$ ths of the nitrogen, $\frac{2}{3}$ ds of the phosphoric acid, and $\frac{7}{8}$ ths of the potash contained in the food and litter consumed by the animals. Rather higher proportions would be recovered in the case of older animals, smaller amounts being retained in the live-weight increase.

The state of combination of the nitrogen in poor and rich dung.

Determinations of ammoniacal and non-ammoniacal nitrogen in each of the samples of dung were made as described above. The results are set out below.

Dung made by	Nitrogen per cent. in fresh dung			Percentage of total nitrogen	
	as ammonia	as organic compounds	Total	as ammonia	as organic compounds
Animals eating roots and hay only...	0·028	0·290	0·318	9	91
Animals eating roots, hay, and cake .	0·203	0·371	0·574	35	65

The figures shew very strikingly the effect on the composition of the dung of the use of a concentrated nitrogenous food such as decorticated cotton cake. Its nitrogen is almost entirely digestible, and consequently is excreted in the urine in the form of readily fermentable compounds which rapidly get transformed into ammonia. This leads to a great increase of ammoniacal nitrogen in the dung. Of the 42·8 lbs. of nitrogen contained in the cake consumed by the two heifers, no less than 23 lbs. can be accounted for as increased ammoniacal nitrogen in their dung. Since ammoniacal nitrogen produces a very obvious effect on the crops to which it is applied, this no doubt is the cause of the great reputation of cake-made dung.

The losses which occur during storage.

As already stated the two lots of dung were sampled twice, with an interval of about 6 months between the two dates, including the hottest months of the year. During this period of storage fermentative changes would no doubt be active, though they were minimised by the solid condition of the dung. Analyses were made on each occasion of sampling, and a comparison of the two sets of figures gives information as to the losses produced by fermentations during summer storage, with formation of ammonium carbonate which would get lost by volatilization. These figures are given below.

	Animals eating roots and hay only				Animals eating roots, hay, and cake			
	Dry matter	Nitrogen	Phosphoric acid	Potash	Dry matter	Nitrogen	Phosphoric acid	Potash
Loss per cent. in making dung.....	38·8	16·8	11·9	13·2	35·0	12·5	14·3	4·1
Loss per cent. in storing dung.....	16·2	10·6	0·0	13·6	18·6	26·9	0·0	24·2
Total loss in making and storing.....	55·0	27·4	11·9	26·8	53·6	39·4	14·3	28·3
Retained in live-weight increase.....	2·6	8·0	20·6	0·4	5·0	9·0	16·4	0·6
Percentage of manurial constituents actually applied to the land ...	42·4	64·6	67·5	72·8	41·4	51·6	69·3	71·1

Several points of considerable interest can be noticed in the above table. Firstly a diet enriched by cake has given a more readily fermentable dung, since the figures shew a distinctly greater loss in

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dry matter from the cake dung than from that made without cake. Secondly a still greater loss has taken place in the nitrogen of the richer dung, and this is no doubt connected with the presence in it of greater proportionate amounts of ammoniacal nitrogen as shewn above. The ammoniacal nitrogen was estimated in the rotted dung. The losses of total and ammoniacal nitrogen are given in the following table.

	No Cake lbs. nitrogen	Cake lbs. nitrogen
Ammoniacal nitrogen in fresh dung	3·2	25·1
„ „ rotted „	1·9	10·0
Loss of ammoniacal nitrogen during storage.....	1·3	15·1
„ „ „ as percentage of total loss...	25	62

The dung of the cake-fed animals contains eight times as much ammoniacal nitrogen as the poorer dung, and about two-thirds of this is lost during storage. This great loss of ammonia accounts for 62 per cent. of the total loss during storage in the richer dung, while in the poorer dung, of the smaller amount of ammonia present only about one-third is lost which accounts for only 25 per cent. of the total loss from this lot of dung. It will be remembered that the assumption was made that no phosphoric acid was lost in storage. There is a certain loss of potash, during storage, and the proportion of the total potash consumed by the animals in food and litter which finally reached the land was only about three-quarters, instead of the whole as estimated by Voelcker and Hall. The amount of phosphoric acid which was found in the rotted dung also falls short of Voelcker and Hall's estimated three-quarters by 6 or 7 per cent. The figures for nitrogen come rather over their limit of 50 per cent. though the amount in the rotted dung from the cake-fed animals cuts it rather fine.

The manurial value of cotton cake.

Since the two pairs of animals consumed practically equal amounts of hay, straw and roots, and since the dung of each pair was similarly treated throughout the experiment, it is possible, taking the no-cake dung as a base-line, to calculate from the figures already given the amounts of the manurial constituents of the cake which were recovered in the dung. The figures for this are given below.

	Dry matter	Nitrogen	Phosph. Acid	Potash
<i>Fresh manure:</i>	lbs.	lbs.	lbs.	lbs.
Animals eating roots, hay, and cake.....	2969	71.0	23.5	—
Animals eating roots and hay only	2590	36.0	8.5	96.9
Constituents of cake recovered in dung	379	35.0	15.0	—
Constituents contained in cake eaten	605	42.8	21.4	16.1
Percentage of manurial constituents of cake recovered in fresh dung	63	82	70	—
<i>Rotted manure:</i>				
Animals eating roots, hay, and cake.....	2051	46.7	23.5	90.0
Animals eating roots and hay only	1873	30.9	8.5	81.6
Constituents of cake recovered in dung	178	15.8	15.0	8.4
Constituents contained in cake eaten	605	42.8	21.4	16.1
Percentage of manurial constituents of cake which actually reached the land	29	37	70	52

The highly fermentable nature of the cake residue is very evident. While 63 per cent. of the dry-matter of the cake was recovered in the fresh dung, less than half that proportion remained in the dung after 6 months' storage. This proneness to fermentation causes great losses of nitrogen, for the fresh dung contains 82 per cent. of the nitrogen of the cake, as against 37 per cent. in the dung when ready for application to the land. This point seems to be one of considerable practical importance for the following reasons.

When a tenant leaves a farm he is compensated by valuation, not for the total manurial constituents contained in the dung he leaves behind in the yards and buildings and in the soil, but for those constituents only which were presumably derived from the foods, such as cakes, which he had purchased during the last years of his tenancy. In the case under consideration compensation would be paid on the manurial residue of 672 lbs. of decorticated cotton cake. If the compensation due on this were valued on the basis of Voelcker and Hall's estimates, payment would be due on half the nitrogen, three-quarters of the phosphoric acid, and the whole of the potash. But these estimates appear to have been based on experiments in which the measurements made were the proportions of the manurial constituents of the whole diet which were recovered in the dung. In other words compensation is assessed on the assumption that the losses in making and storing dung are practically the same for all the constituents of a diet.

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The experiment which is described in the present communication shews clearly that this is not the case, and theoretical considerations seem to support this contention. Thus taking Wolff's figures for the digestibility of the nitrogen of the foods used in the experiment, it appears that of the 48 lbs. of nitrogen consumed as food and litter by the animals receiving no cake, 30 lbs. only would be digested. Subtracting from this the 4 lbs. retained in the form of increased live-weight, it follows that these animals would have excreted in their urine about 26 lbs. of nitrogen. The balance of 18 lbs. would exist in insoluble compounds in the solid excreta, or in the litter. In the same way it is arrived at that the cake-fed animals would excrete about 56 lbs. of soluble nitrogen in their urine and about 26 lbs. in their solid excreta and litter. The richer dung would therefore contain more than twice as much soluble and consequently readily fermentable nitrogen as the poorer, and would be proportionately more liable to suffer loss by fermentation, volatilization, and drainage. If the dung were stored for any length of time before being put on the land, the richer the dung the more rapidly might it be expected to lose nitrogen, and consequently, although more than half the total nitrogen of the food and litter might, with reasonably good management, reach the land, it by no means follows that a quantity of dung, made with the addition of say 1 ton of cake, containing 100 lbs. of nitrogen, would contain 50 lbs. more nitrogen than the dung made from the same amounts of home-grown foods without the addition of the cake. Yet it would be on this 50 lbs. of nitrogen that Voelcker and Hall would estimate for compensation.

In the experiment under discussion, out of 100 lbs. of nitrogen in the cake, only 37 lbs. could be traced in the dung at the time when it was applied to the land. Of this 37 lbs., a considerable proportion was found to be in the form of ammonia, and a still further loss might therefore easily take place if the dung were allowed to lie for any length of time on the surface of the land in dry weather. The actual proportion of the nitrogen of the cake which was recovered in the dung in the experiment varied from 82 per cent. in the fresh dung to 37 per cent. in the rotted dung, and probably even less than 37 per cent. would find its way into the land. The dung was however stored for a longer period, and at a hotter time of year, than is usually the case in farming practice, and the average proportion recovered is therefore probably between the limits found in the experiment for fresh and rotted dung, i.e. between 82 and 37 per cent., and this agrees very well with Voelcker and Hall's estimate of 50 per cent. The point should

not however be lost sight of that the loss in storage and in application to the land falls chiefly on the ammoniacal nitrogen of the cake-made dung, and is so great that the proportion of the nitrogen of the cake which actually finds its way on to the land may, without any flagrant mismanagement, very easily fall below 50 per cent.

Summary.

Two pairs of young heifers were fed on a weighed and analysed diet, and their dung was sampled and analysed both in the fresh and in the rotted states.

It was found that the fresh dung contained about $\frac{3}{4}$ ths of the nitrogen, $\frac{3}{8}$ rds of the phosphoric acid, and $\frac{7}{8}$ ths of the potash consumed by the animals in food and litter.

The dung made by the cake-fed animals was found to be more readily fermentable, and consequently more liable to loss during storage, than that made by the animals fed on roots and hay only.

The loss was found to fall chiefly on the ammoniacal nitrogen in which the cake-made dung is comparatively very rich.

Taking as a base-line the amounts of nitrogen and phosphoric acid in the dung of the animals fed on roots and hay only, it was found that the fresh dung of the cake-fed animals contained 82 per cent. of the nitrogen, and 70 per cent. of the phosphoric acid, of the cake they had consumed.

So great however was the loss of ammoniacal nitrogen from the cake-made dung, that after 6 months' storage under cover in the solid undisturbed state in which it was left in the boxes by the animals, only 37 per cent. of the nitrogen of the cake still remained in the rotted dung.

Dung is not usually kept so long as this, nor through such a hot time of the year, so that the average loss will probably be less than that found in the experiment, and $\frac{1}{2}$ the nitrogen of purchased foods may very well be the average amount recovered in the dung.

The experiment shews however that, without any very flagrant mismanagement, the proportion recovered may fall considerably below $\frac{1}{2}$, especially if the dung suffers further loss while lying on the surface of the land in dry weather.