Farmyard Manure

ITS NATURE, COMPOSITION, AND TREATMENT

C. M. AIKMAN

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NEW AGRICULTURAL WORKS.

FARMYARD MANURE:

ITS NATURE, COMPOSITION, AND TREATMENT.

By C. M. AIKMAN, M.A., B.Sc., F.R.S.E., F.I.C., F.C.S.,

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BY

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PREFACE.

THIS little work on 'Farmyard Manure' is in substance a chapter from a larger work on 'Soils and Manures' on which the author is at present engaged, and which he trusts to have ready for publication ere long. The subject is one of universal interest to the farmer, and no excuse is needed for offering to the agricultural public the following short treatise on the nature and composition of what is still the most important of all manures. In order to render the treatment of the subject as simple as possible, technical statements and tables embodying the results of experiments have been relegated to the Appendix. While the sources of much of the information contained in the following pages are of too varied a nature to admit of acknowledgment, special reference may be made to Dr Heiden's 'Düngerlehre,' Dr Emil von Wolff's excellent little book, 'Die praktische Düngerlehre,' Storer's 'Agricultural Chemistry,' Stephens' 'Book of the Farm,' the Rothamsted Experiments, and lastly, to Mr Warington's excellent little handbook on 'The Chemistry of the Farm,' to the publishers of which—Messrs Vinton & Co., Limited—the author is indebted for permission to reprint in the Appendix several of its valuable tables.

CONTENTS.

INTRODUCTION.

The tendency of modern times towards centralisation, the modern methods of sewage disposal and of cultivation, involving thorough drainage of our soils, and the so-called "intensive" cultivation of our crops, have all combined to render the function of manures at the present day of greater importance than ever before. While it is true the farmer is no longer—as he was a century ago—entirely dependent for his supply of manure on that produced on the farm, and while, therefore, farmyard manure can scarcely be looked upon as an absolute essential, inasmuch as it is a bye-product of the farm, and will always continue to be so, a thorough knowledge of its nature and composition must ever remain for the farmer and agricultural student of the highest importance.

The question of the fertility of the soil is a wide and complex one. It depends on many and various circumstances and conditions. Apart altogether from the influence exerted by climate, latitude, altitude, and exposure, it may be said to be dependent on properties of a physical, chemical, and biological nature.

The first class of properties consist of the absorptive and retentive powers of the soil for water, gases, and heat. These properties depend on the proportion in which the so-called proximate constituents of a soil are present—such as gravel, sand, clay, humus, and lime—as well as on the size of the soil-particles, and on their colour. The chemical composition of the soil furnishes, however, the most important source of fertility. As the plant has to derive a portion of its food from the soil, the possession by the latter of the ingredients constituting this food is a fundamental condition of plant growth. A very small portion of the soil is directly concerned in promoting growth. Some of the necessary ingredients are apt to be lacking in sufficient amount, and it is in making good this want that the chief function of manures consists. The substances in which most soils are generally found to be deficient are *nitrogen*, *phosphoric acid*, and *potash*. Manures, therefore, are chiefly applied to make good this deficiency. While, however, this is so, manures, it must not be lost sight of, perform other and important functions, and may be of value not merely because they supply to the soil nitrogen, phosphoric acid, or potash, but also because they exercise some influence on the soil's mechanical properties, or it may be, in preparing for the plants' use inert fertilising substances. The functions of a manure, therefore, may be very varied, and no manure exemplifies this to a greater extent than farmyard manure.

FARMYARD MANURE.

Farmyard manure is the oldest, and is still, undoubtedly, the most popular, of all manures. It has stood the test of long experience, and has proved its position as one of the most important of all our fertilisers. It is highly desirable, therefore, to make a somewhat detailed examination of its composition, and to see on what the variation in this depends; and, finally, to examine into the mode of its action as a manure.

That it should prove a valuable manure is scarcely to be wondered at, as it is originally formed from vegetable substance, and as it, therefore, contains all the elements present in the plant itself.

Its composition is very variable, and probably no two samples would yield exactly similar analyses. In this fact lies one of the chief difficulties of the treatment of the subject, and all statements made in the following pages as to its chemical composition must be taken as *only approximate.*

We may divide its constituents into three classes.

1. That portion due to *solid excreta.*

2. The liquid portion, largely made up of dilute *urine.*

3. The *straw*, or other material, which is used as litter.

The composition of the manure will vary according to the proportion in which these three substances are present, as well as according to the composition of the substances themselves. It will consequently tend to a clearer apprehension of the subject, if we first examine briefly the chemical composition of the solid excreta and urine of the farm animals.

1. Solid Excreta.—The manurial value of the solid excreta of animals—*i.e.*, the proportion they contain of *nitrogen, phosphoric acid*, and *potash*—depends on a variety of conditions.

The solid excreta of horses, sheep, cows, and pigs, are well known to possess different properties, as well as to vary in their composition.

What, however, has a still greater influence is the nature of the food. This is owing to the fact that the solid excreta is made up of undigested food. We can scarcely expect the same quality of solid excreta from an animal fed on poor diet as from an animal fed on very much richer diet. Again, the percentage of the food voided in the solid excreta varies in the case of different animals.[1]

Another consideration which enters into the question is the age, as well as the treatment, of the animal. A young animal, during the period of its growth, absorbs from its food into its system a larger quantity of the three fertilising substances, nitrogen, phosphoric acid, and potash, than is the case with an adult animal whose weight is neither increasing nor diminishing. A working horse similarly will return more of the nitrogen, phosphates, and potash in its dung than one not at work, and which is permitted to gain in weight. The nature of the composition of the solid excreta, therefore, will depend on the nature of the *food*, *age*, *breed*, *condition*, and *treatment* of the animal.

Let us now investigate shortly the influence of the above considerations. The solid excrements of the common farm animals are generally distinguished from one another according to the rate at which they decompose or ferment on keeping. Thus horse-dung is generally known as a "hot" dung, while cow-dung, on the other hand, is known as "cool." Why this should be so is not absolutely clear. Probably it is owing to the fact that the former contains less water, as well as (and this probably has more to do with it) to the fact that it contains a larger percentage of fertilising matter, especially nitrogen, thus affording conditions

[1] See Appendix, Note I., p. 53.

more favourable for rapid fermentation than in the case of the more moist and less rich cow-dung.

The composition of the solid excreta of various animals, as we have just said, varies with the nature of their food; so that it is impossible to take any analyses as absolutely representing its composition. It may be interesting, however, to compare the analyses of samples of horse-dung with those of some other of the commoner farm animals, with a view to obtaining an *approximate* idea of this difference.

Stoeckhardt has found that in 1000 lb. of the fresh solid excreta of the animals below mentioned, there were the following amounts of *nitrogen*, *phosphoric acid*, and *alkalies*:—

	Water.		Nitrogen.		Phosphoric Acid.		Alkalies.	
				Reduced to		Reduced to		Reduced to
	lb.	per cent.	lb.	per cent.	lb.	per cent.	lb.	per cent.
Horses (winter food) . .	760	76	5	.50	$3\frac{1}{2}$	.35	3	.30
Cows (winter food) . .	840	84	3	.30	$2\frac{1}{2}$	.25	1	.10
Swine (winter food) . .	800	80	6	.60	$4\frac{1}{2}$	.45	5	.50
Sheep (2 lb. hay per diem) .	580	58	$7\frac{1}{2}$	.75	6	.6	3	.30

From the above table it will be seen that the sheep's dung contains the least percentage of *water*, and is richer in *nitrogen* and *phosphoric acid* than any of the other three. The percentage of alkalies, of which the most important is potash, is, however, not so large.

This may be accounted for by the interesting and well-known fact that a large percentage of potash is to be found in the wool of sheep.[1]

The solid excrement of the sheep is, therefore, weight for weight, the most valuable as a manure, as it contains more nitrogen and phosphates than the others, and, at the same time, is much drier.

If, however, we compare the composition of the solid excreta in a dry state, we shall find that the following are the results (basing our calculation on Stoeckhardt's analyses):—

	Nitrogen, per cent.	Phosphoric acid, per cent.	Alkalies, per cent.
Horse . . .	2.08	1.45	1.25
Cow . . .	1.87	1.56	0.62
Pig . . .	3.00	2.25	2.50
Sheep . . .	1.78	1.42	0.71

It will be seen from the above that the dry substance of the solid excreta of the pig is richest in fertilising substances. Too much stress, however, as has already been pointed out, must not be put on any single analysis, as so much depends on various conditions, especially the food.[2] The most reliable method of studying this question, therefore, is to study it in its relation to the food consumed. Wolff has calculated from numerous investigations that,

[1] "The large amount of potash in unwashed wool is very remarkable; a fleece must sometimes contain more potash than the whole body of the shorn sheep."—Warington's 'Chemistry of the Farm,' p. 78.

[2] See Appendix, Note II., p. 53.

with regard to the amount of solid excreta produced by the food, the following percentage of *organic matter*, *nitrogen*, and *mineral substances*, originally present in the dry matter of the food, is voided in the dung:—

	Cow.	Ox.	Sheep.	Horse.	Average.
Organic matter .	39.5	42.5	44.0	44.1	42.5
Nitrogen . .	47.5	33.9	46.7	32.4	40.1
Mineral substances	53.9	64.6	57.9	62.5	59.7

There is one fact to be borne in mind in estimating the manurial value of the dung of different animals —viz., that the quantity of dung voided by one animal is much greater than that voided by another. Thus the amount voided by the cow, for example, is much greater than that voided by the horse, so that, in this way, the inferior quality of the former is, to some extent, compensated for by its greater quantity.

2. Urine.—The solid excreta possess, however, very much less manurial value than the urine. The former, as already stated, are undigested food substances; any fertilising matters which they contain are such as have failed to be digested or absorbed into the animal system. The urine, on the other hand, contains those fertilising substances which have been digested.

The amount of nitrogen and mineral matter, however, in the urine does not represent necessarily the total amount of these substances. Thus, in the case of a growing or fattening animal, there is always a certain amount of these substances being absorbed to build up the animal tissue and put on flesh.

In this respect it will be seen that the composition of urine will vary in the same way as that of the dung does. In the case of the urine, however, there is a compensating influence to be taken into account. Urine is a waste product, and there is more waste in a young than in an adult animal.

Another very important condition which determines the composition of urine, is the nature of the food, especially the quantity of water drunk. This, of course, is obvious; the more water drunk, the poorer must the composition of the urine be. But here again, as in the case of the dung, this is largely compensated for by the total quantity voided—the more dilute the urine, the larger will its quantity be; so that the inferior quality is in this way made up for by its increased quantity.

Keeping in mind, then, the fact we have just stated—viz., that the composition of urine will vary according to different conditions—we may obtain an approximate idea of what its composition is from the following results of analyses by Stoeckhardt. In 1000 parts the following quantities of *water*, *nitrogen*, *phosphoric acid*, and *alkalies* were found to be present.

From the following table it will be seen that the urine of swine (containing 97 per cent of water) is much poorer in nitrogen and alkalies than is the case with the urine of the sheep, horse, or cow. While this is the case, the amount of phosphoric acid it contains is greater than that contained in the sheep's urine.

	Water.		Nitrogen.		Phosphoric Acid.		Alkalies.	
	Per 1000 parts.	Per cent.	Per 1000 parts.	Per cent.	Per 1000 parts.	Per cent.	Per 1000 parts.	Per cent.
Sheep (2 lb. hay per diem)	865	86.5	14	1.4	.5	.050	20	2.0
Swine (winter food)	975	97.5	3	.3	1.25	.125	2	.2
Horses (hay and oats)	890	89.0	12	1.2	...	...	15	1.5
Cows (hay and potatoes)	920	92.0	8	.8	...	...	14	1.4

Phosphoric acid is present in the urine of the farm animals in the most minute traces; practically, it may be considered to be wanting in the urine of the horse and the cow, and is present only in small quantities in sheep's urine. The pig's urine, indeed, contains it in larger quantities, but the percentage is still so small as to justify the statement that the urine of the common farm animals is not a complete manure, and must be supplemented by phosphates, if it is to be used alone. The incomplete nature of urine as a manure constitutes a strong argument in favour of its being applied along with the solid excreta, which contain, as we have seen, considerable quantities of phosphoric acid. It is on this account that the drainings of rotten manure-heaps are more valuable, from a manurial point of view, than urine itself, since these contain the soluble portion of the phosphates in the solid excreta.[1] The urine of all animals, however,

[1] See Appendix, Note XV., p. 64.

is not equally poor in phosphates. In the case of flesh-eating animals, such as the dog, the urine is found to contain them in considerable quantities.

The above tables show that the most valuable urine, weight for weight, is that of the sheep, as it contains the largest amount of alkalies (including potash) and nitrogen; that the urine of the horse comes next; then that of the cow; while, as has already been pointed out, that of the pig is the poorest.

In order to make our survey of the composition of urine uniform with that of the dung, let us see how the urine of the common farm animals compares in the matter of the composition of its dry substance. The following results (basing our calculations on Stoeckhardt's figures, previously given) show this:—

	Nitrogen, per cent.	Phosphoric acid, per cent.	Alkalies per cent.
Pig . . .	12.0	5	8
Horse . . .	10.9	trace	13.6
Sheep . . .	10.4	3.7	14.9
Cow . . .	10.0	trace	17.5

From these figures we see that the dry substance of the urine of the pig is richest in nitrogen and phosphoric acid, but poorest in alkalies, of the four common farm animals; that of the horse comes next in the amount of nitrogen it contains, but that, on the whole, there is very little difference between the horse, cow, and sheep in this respect.[1]

As in the case of the dung, this subject is best studied in relation to the food consumed. We are

[1] See Appendix, Note III., p. 54.

again indebted to Wolff's investigations for valuable information on this point. He has found that the following percentages of *organic matter, nitrogen,* and *mineral substances,* originally present in the dry matter of the food, are voided in the urine:—

	Cow.	Ox.	Sheep.	Horse.	Average.
Organic matter . .	4.0	4.4	2.0	3.3	3.4
Nitrogen . . .	31.0	54.8	42.3	60.7	47.2
Mineral substances .	43.1	34.3	41.0	37.5	39.0

We have now considered briefly the composition of the solid excrements and urine of the common farm animals, and have also enumerated some of the principal causes of the variation in their composition.

The solid excreta consist, as we have seen, of *undigested* food, while the urine contains the manurial ingredients of the food which have been *digested* by the animal system.[1] The latter is, weight for weight, as a rule, very much more valuable as a manure than the former. From the table given in the Appendix[2] it will be seen that the proportions of the nitrogen and ash constituents, originally present in the food consumed, which are voided in the excrements, vary with different circumstances. Wolff, in summarising his results, points out that, as a rule, the solid and liquid excrements will contain about 46 per cent of

[1] The nitrogen present in the urine, it may be well to point out, is derived from the waste of nitrogenous tissue as well as from nitrogenous matter of the food digested.

[2] Note IV., p. 55.

the organic matter, 87.3 of the nitrogen, and 98.7 of mineral matter; while Warington, in summarising his results, points out that, with fattening oxen and sheep and with horses, more than 95 per cent of the nitrogen and 96 per cent or more of the ash constituents are voided in the manure. The pig retains a larger proportion of the nitrogen—about 85 per cent appearing in the manure—while in the milking cow only about 75 per cent are returned in the excrements. Generally speaking, we may say that the nitrogen originally present in the food suffers very little loss in passing through the animal system, and that practically speaking the ash constituents suffer no loss whatever.

As to the distribution of the manurial ingredients, much will depend on the nature of the food. Almost invariably more than a *half* of the total nitrogen excreted will be found in the urine, in many cases very much more.[1] Of the mineral constituents, about a third on the average may be said to be excreted in the urine. Of this mineral matter it may be noted that nearly all the alkalies (potash and soda), or about 98 per cent, are found in the urine. Of phosphoric acid and lime, on the other hand, there are the merest

[1] Warington puts this matter admirably in the following words: "If the food is nitrogenous and easily digested, the nitrogen in the urine will greatly preponderate; if, on the other hand, the food is one imperfectly digested, the nitrogen in the solid excrement may form the larger quantity. When poor hay is given to horses, the nitrogen in the solid excrement will exceed that contained in the urine. On the other hand, corn, cake, and roots yield a large excess of nitrogen in the urine" (Chemistry of the Farm, p. 137).

traces in the urine. Horse-urine, however, is an exception with regard to lime, as it contains about 60 per cent of the lime consumed in the food. For information on the subject of pig-manure the reader is referred to Appendix, Note V.[1]

Before passing from this part of the subject, it may be desirable to place before our readers the composition of the dung and urine taken together, so that we may be able to form some idea of their relative value, weight for weight. As the nitrogen constitutes by far the most valuable portion of the manurial ingredients, it will be sufficient if we compare them as to their percentage of this ingredient.

	Water, per cent.	Nitrogen, per cent.	Calculated on dry substance, per cent.	Analyses by
Sheep . . .	67	.91	2.7	Jürgensen.
Horse . . .	76	.65	2.7	Boussingault.
Pig	82	.61	3.4	Boussingault.
Cow	86	.36	2.6	Boussingault.

From these figures we see that, in their natural condition, the excreta of the sheep are the most valuable; those of the horse and pig coming next; while those of the cow are the poorest, containing one-third as much nitrogen as those of the sheep, and one-half as much as those of the horse and pig. This difference, however, is due almost entirely to the different percentage of water the excreta of the various animals contain in their natural state; for in the dry state they are seen to contain, with the single exception of the pig, practically the same amount.

[1] See p. 55.

In conclusion, then, the important points to be noticed are—

1. That in the passage of the food through the system of the common farm animals, only a very small percentage of the fertilising substances, nitrogen, phosphoric acid, and potash, is assimilated and retained in the animal body; and that, therefore, theoretically at least, the excreta should contain nearly the same amount of fertilising matter as the food originally did.

2. That even in the case of a fattening animal, the loss of fertilising matter sustained by the food in passing through the system is not great.

3. That with regard to the total amount of solid excreta and urine voided, the latter contains, as a rule, more nitrogen than the former; the nitrogen in the urine, further, being more valuable, as it is in a soluble condition.

4. That as regards the distribution of the ash constituents, *lime, phosphoric acid*, and *magnesia* are almost entirely found in the solid excrements; while the urine contains nearly all the *potash*.

5. That the best results can be expected only when the liquid and solid excreta are used together as a manure.

As the composition of the manure depends so largely on the nature of the food, a table will be found in the Appendix, Note VI.,[1] containing the manurial composition of some of the commoner feeding-stuffs.

[1] See p. 56.

3. Litter.—We have now to consider the third constituent of farmyard manure—viz., the *litter*—which generally consists of straw.

The uses of the litter, in addition to providing a dry and comfortable bed for the animal, may be briefly summed up as follows:—

1. To absorb and retain the liquid portion of the excreta.

2. To increase the quantity of the manure, and thus secure its more equal distribution, when applied to the field, than could otherwise be done.

3. To add to its value as a manure, both physically and chemically.

4. To retard and regulate the decomposition of the excreta.

Of course litter also performs a very useful function sanitarily, inasmuch as it serves to keep the stall or byre fresher and cleaner and more free from noxious gases, which it absorbs, than would otherwise be the case.

Straw is almost universally used for this purpose. Besides being one of the bye-products of the farm, it is admirably suited in many ways, both owing to its peculiar shape—its tubular structure being admirably adapted for this purpose—as well as on account of its composition, being largely composed of cellulose, a very absorptive substance. Straw thus possesses considerable absorptive power. In manurial ingredients it is not very rich; for, of the various parts of the ripened plant, straw contains the least percentage of nitrogen and phosphates. This is due to the fact that, as the straw ripens, a considerable proportion of these ingredients pass up from the stalk to the seeds, where they are retained.

Generally speaking, straw may be said to contain not more than *a half per cent* of nitrogen—*i.e.*, 11.2 lb. per ton. Its percentage of nitrogen varies, of course, the recorded analyses[1] for wheat-straw ranging from .22 to .81 per cent, or furnishing an average of .48 per cent—*i.e.*, 10.75 lb. per ton. Barley-straw is somewhat richer in nitrogen, the recorded analyses ranging from .41 to .85 per cent, or giving an average of .57 per cent—*i.e.*, 12.76 lb. per ton; while oat-straw is the richest of the commoner straws, ranging from .32 to 1.12 per cent, an average of .72 per cent—*i.e.*, 16.12 lb. per ton.

Of mineral matter, however, straw contains a very much larger percentage, proportionally, than of nitrogen; for, with the exception of phosphates, there is a considerable quantity of inorganic fertilising matter, in the shape of potash, lime, &c., present in it. Of total ash ingredients, on an average, there are generally about 5 per cent—or 112 lb. per ton. The largest percentage of the fertilising matter in these 5 per cent is potash, which varies in the ashes of the straws of the commoner crops from 30 to 15 per cent. The following table will show the variation in com-

[1] See Heiden's Düngerlehre, vol. ii. p. 58.

position of the straws of some of the commoner farm crops, and may be valuable for purposes of reference. The crops are wheat (winter and summer), barley, oats, and rye (winter and summer), and the amount is also calculated in lb. per ton. The results represent the average of a number of analyses.[1]

COMPOSITION OF STRAW.[2]

	Ash.		Composition of Ash.			Number of Analyses.
			Lb. per ton.			
	Per cent.	Lb. per ton.	Potash.	Phosphoric Acid.	Lime.	
Wheat (winter)	5.54	124.09	18.61	5.05	7.18	8
Wheat (summer)	5.14	115.13	25.76	6.47	7.12	6
Rye (winter)	5.33	119.39	20.61	5.89	9.73	8
Rye (summer)	6.14	137.53	42.41	6.73	10.53	1
Barley	4.90	109.76	26.83	5.75	8.73	8
Oats	5.09	114.01	26.22	4.17	9.12	4

From this table it will be seen that the percentage of phosphates is, as has already been noticed, very small.

[1] The following quantities of nitrogen are found in rye, pea, and bean straw :—

	Ranging from per cent.	Average per cent.	Lb. per ton.
Rye-straw	.30 to .73	.57	12.76
Pea-straw	.76 to 1.61	1.21	27.10
Bean-straw	1.15 to 2.62	1.92	43.00

[2] Heiden's Düngerlehre, vol. i. p. 404.

But while straw is well adapted for the purposes that litter is used for, it is not the only substance. Its almost exclusive use as litter is largely owing to the fact that it is a bye-product of the farm.

Loam as litter.—Generally speaking, any substance which has great absorptive as well as retentive powers for nitrogen and the soluble fertilising matters present in farmyard manure, and whose price is nominal, is well suited for acting as litter. Ordinary loamy soil possesses the above qualifications, and is, moreover, a substance to be had for nothing, and, under certain circumstances and in certain countries, is actually used for this purpose, often along with straw. A great objection against loam, however, is that it forms a dirty litter; it, moreover, possesses a very small percentage of fertilising matter. The tendency, therefore, in using ordinary loam would be to dilute the manure too much, besides retarding fermentation to an undesirable extent. Except, therefore, under very exceptional circumstances, loam is not to be regarded as a good litter.

Peat as litter.—Some kinds of soil, however, are well suited for this purpose. Of these, the best are those rich in organic matter, the so-called peaty soils. Peat, when dried and freed from any earthy matter, forms an excellent absorbent of the liquid portion of the manure, surpassing, in this respect, straw itself. It is, further, generally very much richer in nitrogen—some peats having been found to contain between 4 and 5 per cent of nitrogen. In some thirty samples of peat, analysed by Prof. S. W. Johnson, the percentage of nitrogen varied from .4 to 2.9 per cent, giving an average of 1.5 per cent.

While it has a very great capacity for absorbing liquids, it possesses, in an unequalled degree, the power of retaining the soluble nitrogen compounds. This is undoubtedly one of the most important properties which recommend peat for the purposes of litter.

Some interesting experiments on the value of peat-moss as a litter have been recently carried out by Mr Bernard Dyer.[1] From these experiments Mr Dyer has found that both its liquid-absorbing and liquid-retaining powers are very much greater than those of straw. While straw was only able to absorb three times its weight of water, peat-moss was found to absorb nearly ten times its weight. With regard to its water-retaining power, this was also found to be in excess of that of straw. Both these properties are, it need scarcely be pointed out, of very great value in a litter. Another point of interest in these experiments was the respective amounts of nitrogen absorbed and retained by the peat-moss and the straw. It was found that, in this respect, the peat-moss had again an advantage over the straw. Lastly, the manure produced by the peat-moss was shown to be richer in fertilising

[1] See 'Mark Lane Express,' October 7, 1889, p. 475.

matter than that produced by the use of straw.[1] These experiments are interesting as demonstrating the fact that in peat-moss we have a substance which is capable of acting as an excellent substitute for the more costly straw, which might increasingly be used as a fodder, with great benefit to the farmer.

Another substance which has been suggested as an excellent litter is the common *bracken fern.* According to some analyses made by Mr John Hughes, the bracken, especially if cut in a young state, is a substance of considerable manurial value. When dried it is very much richer in nitrogen, potash, and lime than straw. Its absorbent properties, however, are probably not so great. Where it can easily and cheaply be had, as in many parts of Scotland and Ireland, it might well be used for littering purposes.[2]

Dried leaves have also been used as a litter. Autumn leaves, however, contain a very small percentage of fertilising matter. This is due to the fact that the most of their potash, phosphoric acid, and nitrogen pass into the body of the trees at the approach of winter. According to Professor Storer, dried leaves only contain from .1 to .5 per cent potash, .006 to .3 per cent phosphoric acid, and about .75 per cent of nitrogen. Leaves, however, besides being poor in manurial ingredients, make a bad litter, as they ferment but slowly. There is in this fermentation a

[1] See Appendix, Note VII., p. 57.

[2] For analyses see Appendix, Note VIII., p. 57.

large quantity of cold sour humic acid formed, which seriously impairs the value of the manure.[1]

Having now considered the composition of the three separate ingredients of farmyard manure—viz., the *dung* or *solid excreta*, the *urine*, and the *litter*—we are in a position to consider the composition of farmyard manure. In this connection it will be well to consider separately the manures produced by the different farm animals.

1. Horse-manure.—The composition of horse-manure is perhaps the most uniform of all the manures produced by the different farm animals. This is due to the fact that the food of the horse is generally of the same kind, consisting of oats, hay, and straw.

The total excrements voided by a horse in a day have been calculated, according to the average of experiments by Boussingault and Hofmeister, at 28.11 lb., of which only 6.37 lb. consisted of dry matter.[2] These 28.11 lb. contained .18 lb. of nitrogen and .92 lb. of mineral matter. The amount of straw necessary to absorb this amount of excrement may be stated at from 4 to 6 lb. The amounts of nitrogen

[1] According to Storer, in a ton of autumn leaves of the best quality there would be 6 lb. of potash, less than 3 lb. of phosphoric acid, and 10 or 15 lb. of nitrogen.

[2] Heiden's Düngerlehre, vol. ii. pp. 34, 66. In Boussingault's experiments the food consisted of 15 lb. *hay*, 4.54 lb. *oats*, and 32 lb. water; the total excrements amounting to 31.16 lb., containing 7.42 lb. dry matter. In Hofmeister's experiments the food consisted of 5.23 lb. *hay*, 6.18 lb. *oats*, 1 lb. *chopped straw*, and 25.57 lb. water; the excrements amounting to 25.07 lb., containing 5.32 lb. dry matter.

and mineral matter in 4 lb. of straw are .01 and .23 lb. respectively. The total amount of nitrogen and ash, therefore, in the farmyard manure produced by a horse in one day would be .19 lb. nitrogen and 1.15 lb. mineral matter; or, if we take the larger quantity of straw, somewhat more.

Taking these figures, we find that the amount of manure produced by a horse in a year will be from 11,720 to 12,450 lb. (*i.e.*, from 5¼ to 5½ tons),[1] containing from 69 to 73 lb. nitrogen, and from 420 to 460 lb. mineral matter.[2]

A word or two may be of value regarding the treatment in the stable of horse-manure. The great object to be aimed at is the prevention of loss of valuable fertilising constituents. This loss may be due to two causes. It may be, in the first place, caused by drainage of the soluble matter of the manure; or secondly, it may be due to volatilisation of the volatile constituents.

The first of these two sources of loss depends on the precautions taken in the way of providing a proper impervious flooring to the stable. This source of loss is extremely difficult to prevent, inasmuch as nearly all materials used for flooring absorb a certain percentage of urine. The judicious use of litter, however, will minimise this loss to within a trifling extent.

[1] This is taking no account of the amount of water which the manure will absorb, and which will probably double the quantity.

[2] See Appendix, Note IX., p. 57.

Dr Heiden states that the amount of straw used as litter for the horse in Germany is between 4 to 6 lb. per day. The quantity should be regulated according to the percentage of water the excreta contains; the more watery excreta requiring naturally a larger quantity of litter. The most eminent authorities on this subject recommend that the amount of litter should equal one-fourth of the food in its natural state, or about one-third of its dry substance.

The second source of loss, which is due to volatilisation of the volatile ingredients, may be largely prevented by the use of certain preservatives.

Horse-dung being, comparatively speaking, of a dry nature, it is extremely difficult to effect its thorough mixture with the litter. For this reason the manure formed from horse excreta is particularly liable to rapid fermentation.[1] In the process of fermentation, as will be seen more in detail further on, the nitrogen is converted into carbonate of ammonia. As nitrogen in this form is of an extremely volatile nature, the risks of loss from this source are considerable. As illustrating this fact, it may be mentioned that Boussingault has found by experiment that the total percentage of nitrogen contained by fresh horse-manure might be reduced in the process of fermentation to one-half of its original amount by loss from this source.

[1] The rapid fermentation of horse-manure is due to its mechanical as well as its chemical nature. The horse does not reduce its food to such small pieces, and its urine is rich in nitrogen.

The preservatives used to prevent this volatilisation are technically known as "fixers." This they do by chemically combining with the volatile ammonia and forming non-volatile compounds with it.

Of the acid fixers, hydrochloric and sulphuric acids have been recommended. The former, however, is not well suited for this purpose. It is a strongly fuming acid, and when brought into contact with ammonia forms dense white fumes. The use of sulphuric acid is not open to this objection. Sulphate of ammonia, the salt formed in this case, is one of the most stable (or least volatile) of the compounds of ammonia. If used, it should be largely diluted with water, and the whole mixed with sand. Such a mixture, when sprinkled over the stable-floor in even very small quantities, has been found to effectually prevent any loss of the volatile carbonate of ammonia.

It is not, however, on the whole advisable to use an acid substance as a fixer, since such a substance may act deleteriously on the horses' hoofs.

Such substances as *gypsum*, *copperas*, and *sulphate of magnesia*, while equally efficient, are not open to this objection. The above-mentioned substances owe their efficacy to the fact that they are compounds of sulphuric acid, which, by combining with the volatile ammonia and forming sulphate of ammonia, prevents its escape.

Gypsum, or sulphate of lime, although, comparatively speaking, an insoluble substance, when brought in contact with carbonate of ammonia has been proved to effect the conversion of the ammonia into sulphate of ammonia. It is also believed to retard the decomposition of the manure.[1] Copperas, or ferrous sulphate, while a soluble salt, and while thus acting in a more speedy manner in fixing the ammonia, is not so well suited, owing to the hurtful influence it is well known to possess on plant-life. It is only right to remember that there may be circumstances in which copperas may, in small quantities, act, even beneficially, as a manure, as Griffiths' experiments would seem to indicate. The above objection, however, cannot be urged against sulphate of magnesia. In addition to fixing the ammonia, sulphate of magnesia may very probably fix the soluble phosphoric acid. Kainit, which consists of a mixture of sulphates and chlorides of potassium and magnesium, has also been suggested for this purpose. By using such a fixer, the value of the resulting manure would be much enhanced. In conclusion, it must be remembered that all the above-named fixers act very much in the same way—viz., by converting the volatile carbonate of ammonia into sulphate of ammonia.[2]

2. **Cow-manure.** — The composition of the manure formed from the excrementitious matter of the cow is very much less constant than is the case in the horse-

[1] Schulze recommends one-third of a pound per day of sulphate of lime for each horse.

[2] See Appendix, Note X., p. 58.

manure. An average statement of that composition is therefore very much more difficult to obtain. The number of analyses available for the purpose of forming this average is, however, very large. The manure produced by cows contains a large percentage of water. This is due to the large quantity of water they drink. It has been estimated that milk-cows drink along with their winter food, for every pound of dry substance, 4 lb. of water, and in summer about 6 lb.

According to some experiments by Boussingault, the excrements of a cow in a day amounted to 73.23 lb., of which only 9.92 lb. were dry matter.[1] These excrements contained .256 lb. of nitrogen, and 1.725 lb. of mineral matter. The amount of straw necessary to use as litter for this amount of excrements may be taken at 6 to 10 lb. The manure, therefore, formed by a cow per day would contain from .274 to .286 lb. of nitrogen, and from 2.046 to 2.278 lb. of mineral matter.

In a year this would amount to from 100 to 104.4 lb. of nitrogen, and from 746.8 lb. to 831.5 lb. of mineral matter; or from 6 cwt. 75 lb. to 7 cwt. 47 lb. Cow-dung is, owing to its much more watery nature and poorer quality, very much slower in its fermentation than horse-dung. When applied alone cow-manure is very slow in its action, and makes its influence felt for at least three or four years. It is difficult to spread it evenly over the soil, owing to the fact that,

[1] The food consisted of 30 lb. *potatoes*, 15 lb. *hay*, and 120 lb. *water*.

when somewhat dried, it has a tendency to form hard masses, which, when buried in the soil, may resist decomposition for a very long period. The cause of this is due to the presence of a considerable amount of mucilaginous and resinous matter in the solid excreta, which prevent the entrance of moisture and air into the centre of the mass. This tendency of cow-manure to resist decomposition will be greatly lessened in the case of the excrements of a cow richly fed.

The risks of loss of volatile ammonia are, therefore, in its case not so great as we have seen them to be in the case of the "hot" horse-dung. Notwithstanding this fact, much of what has been said on the use of preservatives for horse-manure may be also applied to the cow-dung. This is owing to the fact that the dung is allowed to accumulate in the court for some time. The amount of straw it is advisable to use as litter varies, as has been said, from 6 to 10 lb. per day. The best method of calculating this amount, according to Dr Heiden, is by taking one-third of the total weight of the dry substance of the food. The above authority also recommends that the straw is best applied in blocks of about one foot in length; and this for the following reasons:—

1. The strewing of it is more convenient.

2. The absorption of the fluid portion is more complete.

3. The cleaning out of the manure from the byre is easier.

4. The manure is more easily distributed when applied to the field.

Among the advantages incidental to allowing the manure to accumulate in the court may be mentioned the following:—

1. The more thorough absorption of the urine by the straw, and, consequently, the more uniform mixture which will be thus effected of the more valuable urine with the less valuable solid excreta.

2. A certain retardation of decomposition effected by the treading under foot of the manure.

3. The protection of the manure from rain and wind, and the securing of a uniform temperature.

Against those advantages must be placed the risk of seriously affecting the health of the animal. Although this is a point of very great importance, it scarcely falls within the scope of this work. It may be pointed out, however, that the judicious use of some of the chemical fixers previously referred to may do much to keep the air of the byre or court free of noxious gases.[1]

3. **Pig-manure.**—The food of the pig is so very variable in its character, that it is wellnigh impossible to obtain anything like an average analysis of its excrements. When the food of the pig is rich, then the manure may be quite equal in quality to the other manures. According to Boussingault, the total amount of excrements, on an average, voided by a pig in twenty-four hours is about 8.32 lb., of which 1.5 lb. is dry

[1] For further analyses of cow-manure, see Appendix, Note XI., p. 60.

matter.[1] The amount of nitrogen these excrements contain is only .05 lb., and of mineral ingredients .313 lb. If we take the amount of straw, most suitable for absorbing this quantity of excrementitious matter, at from 4 to 8 lb., then we shall find that the manure produced by a pig will contain from .06 to .074 lb. nitrogen, and .545 to .772 lb. mineral matter. These quantities, calculated for a year, give from 22 to 27 lb. of nitrogen, and from 1 cwt. 87 lb. to 2 cwt. 57 lb. of mineral matter. That is about as much nitrogen as would be contained in 1¼ to 1½ cwt. of nitrate of soda (95 per cent purity); or from slightly less than 1 cwt. to slightly over 1 cwt. of sulphate of ammonia (97 per cent purity).

As has already been pointed out, the excrements of the pig are, as a rule, very poor in nitrogen. This accounts for the fact that pig-manure is a "cold" manure, slow in fermenting.

4. Sheep-manure.—The dung and the urine of the sheep, as we have already seen, are, weight for weight, the most valuable of any of the common farm animals. The total weight of the excrements voided by a sheep in a day may be taken, on an average,[2] at 3.78 lb., of which .97 lb. is dry matter. These excrements contain .038 lb. of nitrogen and .223 lb. mineral matter. Taking the amount of straw most suitable for absorbing

[1] This is for a pig of 6 to 8 months old, and fed on potatoes.

[2] Taken from a very large number of analyses by a number of experimenters. See Heiden's Düngerlehre, vol. i. p. 99.

this quantity of excrementitious matter at three-fifths of a pound, then the manure produced by a sheep in a day will contain .0429 lb. nitrogen, and .264 lb. mineral matter. That is, in a year the quantities of nitrogen and mineral matter in the manure produced by a sheep would be 15.66 lb. of nitrogen and 96.36 lb. of mineral matter.

From its richness in nitrogen, and from its dry condition, sheep-dung is peculiarly liable to ferment. While richer in fertilising substances than horse-manure, it is not so rapid in its fermentation. This is due to the harder and more compact physical character of the solid excreta. The risks of loss of volatile ammonia are, in its case, exceptionally great. The use of artificial "fixers" is therefore to be strongly recommended.[1]

[1] See Storer, Agricultural Chemistry, vol. ii. p. 96.

A question of great importance is as to the amount of farmyard manure produced on a farm in a year, and its value. This is a question which is extremely difficult to satisfactorily deal with. Various methods of calculating this amount have been resorted to. It may be well to state these pretty fully. Some practical authorities estimate the amount by calculating that every ton of straw should produce 4 tons of manure. Another method consists in estimating the amount from the size of the farm. "It is not very wide of the mark to say that the weight of manure produced by consuming with stock in the yards an acre of turnip crop will be 6 tons, and that an acre of green clover similarly fed will give 5½ tons of manure; an acre of pasture, 5 tons; an acre of wheat-straw, 4½ tons; and an acre of barley or oat straw, 4 tons. One hundred acres of good arable land will produce in a year about 5 tons per acre, or 500 tons" (Professor Scott). Another method is by taking, as the data of calculation, the number of cattle, horses, sheep, &c., producing the manure. Lloyd considers that a fattening animal requires 3 tons of straw in the

Fermentation of farmyard manure.—Having now considered the nature of the different manures produced by the four common farm animals separately, it is of importance to consider the exact nature of the fermentation, decomposition, or putrefaction which takes place in the manure-heap.

It is now more than thirty years since Pasteur showed that the fermentation which ensued on keeping a sample of urine was due to the action of a minute organism, for the propagation of which a certain amount of warmth, air, and moisture, as well as

year, and makes about 12 tons of manure. A farmer, therefore, should make 8 tons of manure for every acre of that part of his land which, in the four-course rotation, is put down to turnips.

The last method consists in taking as the data the amount of food consumed and litter used in the production of the manure. Of these methods Heiden considers the last as alone satisfactory and trustworthy. Applying this method to the horse, he shows, from experiments, that a little over 47 per cent of the dry matter of its food has been proved to be voided in the solid and liquid excreta. Taking the average percentage of water in the excreta as about 77.5, the percentage of dry matter in the excreta will be 22.5. That is, every pound of dry matter in the food eaten by the horse yields a little over 2 lb. of excrementitious matter. To this of course must be added the amount of straw used as litter, which may be taken at 6.5 lb.

From these data we may calculate the amount of manure produced in a year by a horse, making certain assumptions as to the amount of work performed. This Heiden does by assuming that a horse works 260 days, of twelve hours each, in the course of a year, or 130 whole days, spending 235 days in the stall. Calculating from the above data, he estimates that a well-fed working horse will produce about 50 lb. of manure in a day, or 6.5 tons in a year. Of course this does not necessarily represent all the manure actually produced by the horse, but how much of the remaining portion of the manure actually finds its way to the farm it is impossible to say. According to the

the presence of certain food constituents, especially nitrogenous bodies, were necessary.

Subsequent researches by Pasteur and others have conclusively demonstrated that the micro-organic life, instrumental in effecting the putrefaction or decay of organic matter of any kind, may be divided into two great classes:—

1. Those which require a plentiful supply of oxygen for their development, and which, when bereft of oxygen, die—known as *aerobies.*

2. Those which, on the contrary, develop in the

'Book of the Farm,' Division III. p. 98, a farm-horse makes about 12 tons of manure in a year.

It has been calculated that cows void about 48 per cent of the dry matter of their food in the solid and liquid excreta, which contains of water, on an average, 87.5 per cent. That is, every pound of dry matter will furnish 3.84 lb. of total excreta. By adding the necessary amount of straw for litter (which may be taken at one-third the weight of the dry matter of the fodder), Heiden calculates that an ox weighing 1000 lb. should produce 113 lb. of manure in a day, or 20 tons in a year. The 'Book of the Farm,' Division III. p. 98, gives the annual amount at from 10 to 14 tons. According to Wolff, one may assume that on an average the fresh excrements (both liquid and solid) of the common farm animals (with the exception of the pig) contain of every 100 lb. of dry matter in the food consumed about 50 lb., or a half. Estimating the dry matter in the litter used at equal to about $\frac{1}{4}$ of the dry matter of the food, this would mean that for every 100 lb. of dry matter consumed in food there would be 75 lb. of dry manure (viz., 50 lb. dry excrements + 25 lb. dry litter), which would yield 300 lb. of farmyard manure in the wet state—*i.e.*, with 75 per cent water. The amount of food daily required per every 1000 lb. of live weight of the common farm animals may be taken, roughly speaking, at 24 lb. dry food material and 6 lb. of straw as litter. The daily production of manure for 1000 lb. of live weight would amount, therefore, to 18 lb. of dry, or 72 lb. wet manure.

complete absence of oxygen, and which, when exposed to oxygen, die—known as *anaerobies*.

In the fermentation of the manure-heap, therefore, we must conceive of the two classes of organisms as the active agents. In the interior portion of the manure-heap, where the supply of oxygen is necessarily limited, the fermentation going on there is effected by means of the anaerobic organism — *i.e.*, the organism which does not require oxygen; while on the surface portion, which is exposed to the air, the aerobic (or oxygen-requiring) organism is similarly active. Gradually, as decay progresses, the aerobic organisms increase in number. It is through their instrumentality that the final products of decomposition are largely produced. The functions of the anaerobic organisms may be, on the contrary, regarded as largely preparatory in their nature. By breaking up the complex organic substances in the manure into new and simpler forms, they advance the process of putrefaction through the initial stages, and when this is accomplished, they die and give place to the aerobic, which, as we have just seen, effect the final transformation of the organic matter into such simple substances as *water* and *carbonic acid gas*.

The conditions influencing the fermentation of farmyard manure may be summed up as follows:—

1. *Temperature.*—The higher the temperature the more rapidly will the manure decay.

2. *Openness to the air.*—Of course it will be seen

that the effect of exposing the manure to the action of the air is to induce the development of the aerobic type of organism, and thus to promote more rapid fermentation. If, on the other hand, the manure be impacted, the slower but more regular fermentation, due to the anaerobic type of organism, will be chiefly promoted. It must be remembered that in the proper rotting of farmyard manure, both kinds of fermentation should be fostered. It is, in fact, on the careful regulation of the two classes of fermentation that the successful rotting of the manure depends. It must further be remembered that, even with a certain amount of openness in a manure-heap, anaerobic fermentation may take place. This is due to the fact that the evolution of carbonic acid gas, in such a case, is so great as to exclude the access of the atmospheric oxygen into the pores of the heap.

3. The *dampness* of the manure-heap is another important influence. This, of course, will act in two ways: first, by lowering the temperature. Where the manure-heap is found to be suffering from "fire-fang," the common method in practice is to lower the temperature by moistening the heap with water. Secondly, it acts as a retarder of fermentation by limiting the supply of atmospheric oxygen, and thus preventing, as we have just seen, aerobic fermentation.

4. The fourth chief influence in regulating fermentation of the manure-heap is its *composition*, and more especially the amount of nitrogen it contains in a solu-

ble form. The rate at which fermentation takes place in any organic substance may be said chiefly to depend on the percentage of soluble nitrogenous matter it contains; the greater this is in amount, the more quickly does fermentation go on. There are always a number of soluble nitrogenous bodies in farmyard manure. These are chiefly found in the urine, such as *urea, uric* and *hippuric acids,* and *ammonia* salts.

Products of decomposition of farmyard manure.—The most important of the changes which take place in the rotting of farmyard manure may be briefly enumerated as follows:—

1. The gradual conversion into gases of a large portion of the organic elements in the manure. Of these gaseous products the most abundant is *carbonic acid gas* (CO_2). It is in this form that the carbonaceous matter which constitutes the chief portion of the manure escapes into the air. Carbon also escapes into the air, combined with hydrogen, in the form of *carburetted hydrogen* or *marsh-gas* (CH_4), a product of the decomposition of organic matter in the presence of a large quantity of water. This gas is consequently found bubbling up through stagnant water. Next to carbonic acid gas, *water* (H_2O) is the most abundant gaseous product of decomposition. The nitrogen present in the manure, in different forms, is converted by the process of decomposition chiefly into *ammonia,* which, combining with the carbonic acid, forms carbonate of ammonia, a very volatile salt. It is to this fact that one of the

great sources of loss in the decomposition of farmyard manure is due. If the temperature of the manure-heap be permitted to rise too high, the carbonate of ammonia volatilises. It is probable, also, that a not inconsiderable portion of the nitrogen escapes into the air in the free state. The last of the most important gaseous products of decomposition are *sulphuretted* and *phosphoretted hydrogen.* It is to these gases that much of the smell of rotting farmyard manure is due.

2. The second class of substances formed are *soluble organic acids,* such as *humic* and *ulmic acids.* The function performed by these acids is a very important one. They unite with the ammonia and the alkali substances in the mineral portion of the manure, forming humates and ulmates of ammonia, potash, &c. It is these ulmates that form the black liquor which oozes out from the manure-heap.

In very rotten farmyard manure traces of *nitric acid* may be found, but it must be remembered that the formation of nitrates is practically impossible under the ordinary conditions of active fermentation of farmyard manure, except perhaps in its very last stages.

3. The third class of changes taking place have to do with the mineral portion of the manure. The result of the formation of so much carbonic and other organic acids is to increase the amount of *soluble* mineral matter very considerably.

Analyses of farmyard manure.—It is chiefly to the valuable researches of the late Dr Augustus Voelcker that we owe our knowledge of the composition of old and fresh farmyard manure. All interested in this important question should peruse the original papers on this subject contributed to the 'Journal of the Royal Agricultural Society' by Dr Voelcker. Typical analyses illustrating the variation in the composition of farmyard manure at different stages of decomposition will be found in the Appendix.[1] From what has been already said, it is obvious that the composition of farmyard manure is of a very variable nature.

The quantity of moisture naturally varies most, and this variation will depend on the age of the manure, and the conditions under which it is permitted to decay. It may be taken at from a minimum of 65 per cent in fresh, to 80 per cent in well-rotted manure. The total organic matter may be taken at from 13 to 14 per cent; containing nitrogen, .4 to .65 per cent. The total mineral matter will range from about 4 to 6.5 per cent, containing of potash from .4 to .7 per cent, and of phosphoric acid from .2 to .4 per cent.[2]

As Mr Warington[3] has pointed out, one ton of farmyard manure would thus contain 9 to 15 lb. of nitrogen, about the same quantity of potash, and 4 to 9 lb. of phosphoric acid. These quantities of nitrogen

[1] See Appendix, Note XII., p. 60.

[2] See Heiden's Düngerlehre, vol. ii. p. 156.

[3] Warington, Chemistry of the Farm, p. 33.

and phosphoric acid, calculated to (95 per cent) nitrate of soda, and (97 per cent) sulphate of ammonia, and (25 per cent) superphosphate, give respectively 57.25 to 96 lb. nitrate of soda, 45 to 75 lb. sulphate of ammonia, and 35 to 79 lb. superphosphate. That is, in order to apply as much nitrogen to the soil as is contained in one ton of nitrate of soda, we should require to use from 23 to 41 tons of farmyard manure; similarly one ton of sulphate of ammonia contains as much nitrogen as 30 to 50 tons farmyard manure. In the same way one ton superphosphate of lime contains as much phosphoric acid as 28 to 64 tons farmyard manure.

The value of rotten manure is, weight for weight, greater than that of fresh manure. This is due to the fact that, while the water increases in amount, the loss of organic matter of a non-nitrogenous nature more than counterbalances the increase in water; the manure, therefore, becomes more concentrated in quality. The loss on the total weight, according to Wolff, in the rotting of farmyard manure, should not exceed in two or three months' time 16 to 20 per cent—viz., a sixth to a fifth of its entire weight. Not only, however, does the manure become richer in manurial ingredients, but the forms in which the manurial ingredients are present in rotten manure are more valuable, as they are more soluble. These statements must not be taken as proving that it is more economical to apply farmyard manure in a rotten condition than in a fresh one. The distinction must not be lost sight of which exists between relative increase—increase in the percentage of valuable constituents—and absolute increase. The increase in the value of the manure by the changes of the manurial ingredients from the insoluble to the soluble condition may be effected at the expense of a considerable amount of absolute loss of these valuable ingredients. This is a point which is probably too often left out of account in discussing the relative merits of fresh and rotten farmyard manure; and it is important that it should be clearly understood. In the words of the late Dr Voelcker: "Direct experiments have shown that 100 cwt. of fresh farmyard manure are reduced to 80 cwt. if allowed to lie till the straw is half rotten; 100 cwt. of fresh farmyard manure are reduced to 60 cwt. if allowed to ferment till it becomes 'fat or cheesy'; 100 cwt. of fresh farmyard manure are reduced to 40-50 cwt. if completely decomposed. This loss not only affects the water and other less valuable constituents of farmyard manure, but also its most fertilising ingredients. Chemical analysis has shown that 100 cwt. of common farmyard manure contain about 40 lb. of nitrogen, and that during fermentation in the first period 5 lb. of nitrogen are dissipated in the form of volatile ammonia; in the second, 10 lb.; in the third, 20 lb. Completely decomposed common manure has thus lost about one-half of its most valuable constituent." While, of course, a very great amount of absolute loss of the valuable constituents—the nitrogen and ash constituents—of farmyard manure may take place through volatilisation and drainage, by taking requisite precautions this loss may be very much minimised. As regards the total loss, this, in two or three months' time, should only amount to 16 to 20 per cent—or one-sixth to one-fifth of the weight.[1] The use of fixers, to which reference has already been made, will greatly minimise this loss. The application of fixers is best made to the manure when still in the stall or byre. The health of the animal benefits by so doing, while the manure is at once guarded against loss from this source.

As to the relative merits of covered and uncovered manure-heaps, much difference of opinion exists. It is one of these questions which does not admit of final decision one way or another, as it depends so largely on the individual circumstances of each case. That manure produced under cover is more valuable than manure made in the open is readily granted. The question, however, is as to whether the increase in its value is sufficiently great to warrant the extra expense involved in building covered courts. This depends on the individual circumstances of each case, and cannot be decided in a general way. For experiments on the relative value of manure made under cover and in the open, see Appendix.[2]

The method of applying farmyard manure to the

[1] See Appendix, Note XIII., p. 62. [2] Note XIV., p. 63.

field is a question which belongs more to the practical farmer than to the scientist, and must be largely decided by economic considerations. There is an aspect, however, of the question which may well be treated here. The first point in the production of good manure is in connection with its even distribution. It is of great importance that the excrements of the different farm animals be thoroughly mixed together. By the intimate incorporation of the "hot" horse-dung with the "cold" cow and pig dung, uniform fermentation is secured. Fire-fang—or too rapid fermentation—may occur from this not being properly done, and from the manure becoming too dry. It is important, also, as we shall see immediately, to have the manure uniform in quality when applied to the field. The manure ought to be firmly trodden down to moderate the rate of fermentation. Where the manure-heap is exposed to rain, the quantity of water it will naturally receive will probably be quite sufficient, if indeed not too much, to ensure a proper rate of fermentation—except, perhaps, in very warm weather. The great point to be aimed at is to ensure regular fermentation. What has to be especially avoided is any sudden exposure of the manure to large quantities of water. The result of such a washing out of the soluble nitrogen is to retard fermentation, besides incurring the risk of great actual loss by drainage.[1]

Application of farmyard manure to the field.—In

[1] See Appendix, Note XV., p. 64.

applying the manure to the field, and before ploughing it in, two methods of procedure may be pursued. First, the manure may be set out in heaps, larger or smaller, over the field, and be allowed to remain in these heaps some time before being spread; and secondly, it may be directly spread broadcast over the field, and thus allowed to lie for some time. Lastly, the manure may be ploughed in immediately; and it may be stated that such a method is, where circumstances permit, the safest and most economical method.

In discussing the merits and demerits of these two methods, Dr Heiden points out, first, with regard to the distribution of the manure in small heaps over the field, that this is not to be recommended on the following grounds:—

1. Because the chances of loss by volatilisation are thereby increased. The manure is distributed several times instead of only once or twice.

2. It is apt to ensure unequal distribution. The separate heaps run the risk of losing their soluble nitrogenous matter, which soaks into the ground beneath the heaps. The other portions of the field not covered by the manure-heaps are thus manured with washed-out farmyard manure, bereft of its most valuable constituents. The result is, that while certain portions of the field are too strongly manured, other portions are too weakly manured.

3. The proper fermentation of the manure is apt to

be interfered with by the loss of that which is its most important agent—viz., the soluble nitrogenous matter, and also by the drying action of the wind.

The same objections hold good to a large extent with regard to the setting out in the fields of the manure in large heaps. The risks of loss, in one respect, may be said to be less, owing to the smaller surface presented; on the other hand, they may be greater, owing to fermentation taking place more quickly. Agricultural practice, however, often renders this custom necessary, and if precautions are taken not to let the heap lie too long, and to cover it over with earth, the risk of serious loss may be rendered inconsiderable.

With regard to the second method of procedure—viz., the spreading of the manure broadcast over the field, and allowing it thus to lie—Dr Heiden is of opinion that this should only be done when the field is level. In the case of uneven ground the risks are, of course, obvious. It has been affirmed that, by allowing farmyard manure thus to lie exposed for some time, an important loss of volatile ammonia—carbonate of ammona—is apt to take place. This could only take place where the former treatment of the farmyard manure had been bad. Hellriegel has shown that in the case of properly prepared farmyard manure there is no danger of loss in this way. The absorptive power of the soil for ammonia, it must be remembered, is very great, and the amount of volatile ammonia in farmyard manure is relatively so small that it is scarcely possible that any could escape in this way. Hellriegel's experiments have demonstrated this in a very striking way. He has found that in the case of a chalky soil, and during the summer and autumn months, practically no loss of ammonia takes place. The following considerations may be further urged in support of this method of application, as against immediately ploughing in the manure, viz.:—

1. That fermentation takes place more quickly.

2. That it results in a more equable distribution of the manurial constituents in the dung, by gradually and thoroughly incorporating the liquid portion of the manure with the soil-particles.

Against, however, these undoubted advantages, one serious disadvantage may be urged — viz., that the manure, before being ploughed in, becomes robbed to a large extent of its soluble nitrogenous compounds, which, as we have repeatedly observed, are so necessary for fermentation; and that, therefore, when it is ploughed in, it does not so readily ferment. This being so, it is highly advisable, in the case of light or sandy soils, not to follow such a practice, but to plough the manure directly in.

As to the depth to which it is advisable to plough the manure in, it may be here noticed that it should not be too deep, so as to permit of the access of sufficient moisture to ensure proper fermentation, and to prevent rapid washing down of nitrates to the drains.

Lastly, it need scarcely be pointed out that it is highly important to have the manure evenly and thoroughly incorporated with the soil - particles. Where the manure is permitted to cake together in lumps, it may successfully resist the action of fermentation for several years.

Value and function of farmyard manure.—Practical experience has long demonstrated the fact that farmyard manure is, taking it all round, the most valuable, and admits of the most universal application, of all manures; and science has done much to explain the reason of this. The influence of farmyard manure is so many-sided that it is difficult even to enumerate its different functions. As has already been pointed out, its indirect value as a manure is probably as great as, if indeed even not greater than, its direct value. In concluding our study of farmyard manure, we shall endeavour to summarise, in as brief a manner as possible, its chief properties.

First, as to its value as a supplier of the necessary elements of plant-food. This, there can be little doubt, has been, and still is, grossly exaggerated by the ordinary farmer. Much has been claimed for it as a "general" manure. How far it merits pre-eminence on this score among other manures will be seen in the sequel. It is true that, since it is composed of vegetable matter, it contains all the necessary plant ingredients. As has been shown in the introduction, there is practically in the case of most soils no necessity to add in a manure any more than the three ingredients, *nitrogen, phosphoric acid*, and *potash.* Its value, then, as a direct manure must depend on the quantity and proportion in which these three ingredients are present. These substances, as we have already seen, it contains only in very small quantities. It is, judged from this point of view, a comparatively poor manure. Furthermore, only a certain percentage of these substances are in a soluble or immediately available condition,—in this respect the rotten manure being very much more valuable than the fresh manure.

Again, a point of great importance in a universal manure is the proportion in which the necessary plant-foods are present. If it be asked, Are the nitrogen, phosphoric acid, and potash in farmyard manure present in the proportion in which crops require these constituents? the answer must be in the negative. Heiden[1] has very strikingly illustrated this point, in so far as the relations between the two ash ingredients are concerned, by some computations as to the amount which would be removed from the soil in the course of different rotations.[2] In the case of five different rotations, it was found that the ratio between the potash and phosphoric acid removed was as follows:[3] (1) 2.96 to 1; (2) 2.76 to 1; (3) 2.95 to 1; (4) 4.13 to 1;

[1] See Heiden's Düngerlehre, vol. ii. p. 171.

[2] For full details see Appendix, Note XVI., p. 64.

[3] Storer reproduces these results in his 'Agricultural Chemistry,' vol. ii. p. 21.

(5) 3.78 to 1. This would give a mean of 3.32 to 1. This is not the ratio in which these ingredients are generally present in farmyard manure. Farmyard manure may be said to be much richer in the mineral constituents of plants than in nitrogen. Professor Heiden found that in the case of a farm at Waldau, the crops in the course of ten years removed from a *morgen* (.631 of an acre) the following quantities :—

	lb.
Nitrogen	329
Potash	263
Phosphoric acid	121

In order to supply these amounts the following quantities of manure would require to be supplied :—

1. For the nitrogen, 26 or 27 tons (manure containing .606 per cent nitrogen).
2. For the potash, 20 to 25 tons (manure containing .672 per cent potash).
3. For the phosphoric acid, 13 to 19 tons (manure containing .315 per cent phosphoric acid).

From the above it will be seen that farmyard manure contains too little nitrogen in proportion to its ash ingredients.

It is not merely the amount of fertilising ingredients removed by the crop we have to take into account in estimating the value of certain manurial ingredients for the different crops. Two other considerations have to be remembered—viz., the amount of the constituents already present in the soil, and the ability of the different crops to obtain the ingredients from the soil. If we take into account these two considerations in estimating the value of farmyard manure as a general manure, we shall find that they accentuate the inadequacy of the ratio existing between the nitrogen and the mineral ingredients. Messrs Lawes and Gilbert have found in the Rothamsted experiments with farmyard manure that while it restored the mineral ingredients, it was inadequate as a sufficient source of nitrogen. Nitrogen is, of all manurial ingredients, in least abundance in soils. It is consequently found that the ingredient in which farmyard manure requires to be reinforced is nitrogen. With regard to phosphoric acid and potash, it has already been shown that the ratio between them is probably greater than that in a good average manure. We should, arguing from this alone, be inclined to think that farmyard manure would be best reinforced with potash. The reverse, as every farmer knows, is the case, however. This is due, first, to the fact that the potash, unlike the phosphoric acid, is entirely of a soluble nature, and therefore immediately available for the plant's needs; and secondly, to the fact that the necessity for the application of potash as a manure is generally not nearly so great as in the case of phosphoric acid. The result is that farmyard manure will be, as a rule, more valuably supplemented by phosphoric acid than by potash.

Another point of great importance in estimating the value of farmyard manure as a chemical manure, is the inferior value possessed by much of the nitrogen it contains, as compared with the nitrogen in such artificial manures as nitrate of soda and sulphate of ammonia. According to the Rothamsted experiments, weight for weight, the nitrogen in farmyard manure is not half as valuable as it is in sulphate of ammonia. Much of the nitrogen becomes only very slowly available; not a little of it perhaps actually takes years to be converted into nitrates.[1]

Thus, with regard to the direct value of farmyard manure as a manure, we have seen—

1. That it contains a very small quantity of the three fertilising ingredients.

[1] This aspect of farmyard manure has been ably stated by Mr F. J. Cooke, a well-known Norfolk farmer. In commenting on the results of the Rothamsted experiments, he says: "It is clear enough that the faith of the farmer in the soil-enriching character of his home-made manure is amply justified, the only question being, indeed, if this quality be not too highly appreciated. It is not, after all, so much by the fattening of our land as by the bounty of the crop grown upon it that we reap the fruit of our exertions. The man of scientific mind keeps his purpose fixed on the *production of good crops* mainly, and the cheapest way to grow them. The experiments under consideration show that richness of land may be purchased much too dearly, and that richness of crop by no means bears the necessary relation to richness of soil which has sometimes been imagined. We may boast of the 'lasting qualities' of our dung, but the answer of science by these experiments is, that so great is the last that the life of one man may not be long enough to exhaust it. In the extravagant use of dung, therefore, such considerations, amongst many others, as length of purse, as well as length and character of tenure, must clearly be taken into account."

2. That the proportion in which these three ingredients are present is not the best proportion for the requirements of crops.
3. That the form in which a portion of these ingredients—nitrogen and phosphoric acid—is present is not of the most valuable kind.

It is consequently not as a direct chemical manure that farmyard manure is pre-eminently valuable. We must seek for perhaps its most valuable properties in its indirect influence.

1. It adds to the soil a large quantity of organic matter. Most soils are improved by the addition of *humus*. The water-absorbing and retaining powers of a soil are increased by this addition of *humus*, while it enables the soil to attract an increased amount of moisture from the air. This is often of great importance, as in the period of germination of seed.[1] The influence it exerts on the texture of the soil in the process of fermentation is also very great. This is especially so in soils whose texture is too close, such as heavy clayey soils. It opens up their pores to the air, and renders them more friable. Where such an influence is most required, as in clayey soils, the manure ought to be applied in a fresh condition, so that the maximum influence exerted by the manure in this direction may be experienced. On light soils, on the contrary,

[1] See paper on "Manurial Experiments with Turnips" by author, in Journal of Highland and Agricultural Society of Scotland, 1891.

whose friability and openness are already too great, and which do not require to be increased, the manure will be best applied in a rotten condition. It adds, further, greatly to the heat of the soils by its decomposition. Thus on cold damp soils it effects one very marked benefit. The influence it exerts in its decomposition upon the fertilising ingredients present in the soil is also by no means inconsiderable. In the process of its fermentation large quantities of carbonic acid gas are generated. This carbonic acid probably acts in a double capacity. It will, in the first place, greatly increase the solvent power of the soil-water, and thus enable it to set free an increased amount of mineral plant-food; and secondly, it will help to conserve a certain quantity of the soil-nitrogen, by preventing its conversion into nitrates.

As its indirect and mechanical properties are greatest when in its fresh condition, it will be better to apply it in that condition to soils most lacking in these mechanical properties. We may therefore say that farmyard manure is best applied in a rotted condition to light sandy soils, and to soils in a high state of cultivation, where its mechanical properties are not so much required.

An important point still remains to be discussed—viz., the rate at which the farmyard manure should be applied. This, of course, should naturally depend on a variety of circumstances—the amount of artificial manures used as supplementary to the farmyard manure, the frequency of its application, and the nature of the soil.

These considerations naturally vary so much, that the quantities of farmyard manure it is advisable to apply in different cases are widely different. There is a strong probability that the rate at which farmyard manure has been applied in the past has been grossly in excess of what could be profitably employed. Opinion is gaining ground among practical farmers, that smaller and more frequent applications of farmyard manure to the soil would be fraught with better results than the older custom of applying a large dressing at a time. This is an opinion in the support of which science can urge strong arguments. It is only of late years that we have come to recognise sufficiently the various risks which all fertilisers are subject to in the soil, and the importance, therefore, of minimising these risks as much as possible by putting into the soil at one time only as much manure as it is safely able to retain.

"The famous old German writer, Thaer, regarded 17 or 18 tons as an abundant dressing; 14 tons he called good, and 8 or 9 tons light. Other German authorities speak of 7 to 10 tons as light, 12 to 18 tons as usual, 20 or more tons as heavy, and 30 tons as a very heavy application."[1]

In the new edition of Stephens' 'Book of the Farm'[2]

[1] Storer's Agricultural Chemistry, vol. i. p. 498.

[2] Division III. p. 130.

from 8 to 12 tons per acre for roots, and from 15 to 20 tons for potatoes, along with artificials, which may cost from 25s. to 60s. per acre additional, are quoted as general dressings.

The majority of recent experiments with farmyard manure would seem to indicate that, even in the case of what are considered small dressings, the extra return in crop the first year after application is not such as to cover the expense of the manure. Of course, as is commonly pointed out, the effect of farmyard manure is of a lasting nature, and is probably felt throughout the whole rotation, or even longer. This, to a certain extent, is no doubt true; still it may be strongly doubted whether farmyard manure is, after all, an economical manure, as compared with artificial manures. The desirability of manuring the soil and not the crop is, in this age of keen competition, no longer believed in; and the Rothamsted experiments have shown that it is highly doubtful whether even the soil benefits to anything like a commensurate extent by the application of large quantities of farmyard manure.

APPENDIX.

NOTE I. (p. 3).

Difference in Amount of Excreta voided for Food consumed.

With regard to the difference in the composition of the solid excreta voided by different fattening animals, fed on the same amount of food, see Warington's 'Chemistry of the Farm,' p. 125, where it is shown that for equal amount of live weight, the sheep produces on the same weight of dry food very much more manure than the pig, while the ox produces even more than the sheep. Of course this does not refer to the total amount of manure produced by the different animals, but only to the amount of manure produced from the consumption of equal quantities of food. This would seem to be owing to the greater capacity the pig has for assimilating its food.

NOTE II. (p. 5).

Solid Excreta voided by Sheep, Oxen, and Cows.

To contrast with the analyses given by Stoeckhardt, it may be well to cite those quoted by Warington ('Chemistry of the Farm,' p. 138) :—

I.—SHEEP (fed on *meadow-hay*).

	Solid Excrement. Fresh.	Dry.
Water	66.2	...
Organic matter	30.3	89.6
Ash	3.5	10.4
Nitrogen	.7	2.0

II.—OXEN (fed on *clover-hay* and *oat-straw*, with 8 lb. *beans* per day).

	Fresh.	Dry.
Water	86.3	...
Organic matter	12.3	89.7
Ash	1.4	10.3
Nitrogen	.3	1.9

III.—COWS (fed on *mangels* and *lucerne hay*).

	Mangels.	Lucerne hay.
Water	83.00	79.70
Nitrogen	.33	.34
Phosphoric acid	.24	.16
Potash	.14	.23

NOTE III. (p. 9).

URINE VOIDED BY SHEEP, OXEN, AND COWS.

The following are Warington's results for urine, the animals being fed as in Note II. :—

	Sheep.		Oxen.	
	Fresh.	Dry.	Fresh.	Dry.
Water	85.7	...	94.1	...
Organic matter	8.7	61.0	3.7	63.0
Ash	5.6	39.0	2.2	37.0
Nitrogen	1.4	9.6	1.2	20.6

Cows.

	Mangels.	Lucerne hay.
Water	95.94	88.25
Nitrogen	.12	1.54
Phosphoric acid	.01	.006
Potash	.59	1.69

NOTE IV. (p. 10).

Percentage of Food voided in the Solid and Liquid Excrements.

According to Wolff, the following table shows the percentage of the dry substance of the food which is voided in the solid and liquid excrements of the cow, ox, sheep, and horse :—

	Cow.	Ox.	Sheep.	Horse.	Average.
Solid excreta .	38.0	44.0	42.6	46.7	42.8
Urine . .	5.8	6.3	6.8	5.7	6.2
Total . .	43.8	50.3	49.4	52.4	49.0

NOTE V. (p. 12).

Pig Excrements.

The excrements voided by pigs are poor in manurial constituents, because the food on which they are fed is generally of a very poor nature. In their case the urine is always very much richer in manurial ingredients than the solid excreta. The relative composition of the solid excreta and the urine will be best illustrated by quoting some experiments carried out by Wolff on this subject. The experiments were carried out with two pigs nine and a half months old, and each 121.9 kilogrammes (a kilogramme is equal to about $2\frac{1}{4}$ lb.) in weight. The first consumed daily 1000 grammes of barley, 5000 grammes of potatoes, and 2572 grammes of sour milk. The second one consumed the same quantities of potatoes and sour milk as the first, and 1000 grammes of peas. The following table gives the results of excreta and urine daily voided, in grammes :—

		Dry substance.	Nitrogen.	Ash.	Potash.	Lime.	Magnesia.	Phosphoric acid.
Solid excreta	I.	217.7	8.7	28.6	7.3	4.4	3.0	10.3
	II.	161.1	9.1	31.1	5.9	4.9	2.8	11.1
Urine	I.	112.8	19.3	56.2	33.0	0.4	0.9	6.7
	II.	137.7	30.6	62.2	37.1	0.2	1.1	7.1

NOTE VI. (p. 13).

MANURIAL CONSTITUENTS IN 1000 PARTS OF ORDINARY FOODS (Warington's 'Chemistry of the Farm,' p. 139).

	Dry matter.	Nitrogen.	Potash.	Phosphoric acid.
Cotton-cake, decorticated	918	70.4	15.8	30.5
Rape-cake . .	887	50.5	13.0	20.0
Linseed-cake . .	883	43.2	12.5	16.2
Cotton-cake, undecorticated	878	33.3	20.0	22.7
Linseed . . .	882	32.8	10.0	13.5
Palm-kernel meal, English	930	25.0	5.5	12.2
Beans . . .	855	40.8	12.9	12.1
Peas . . .	857	35.8	10.1	8.4
Malt-dust . .	905	37.9	20.8	18.2
Bran . . .	860	23.2	15.3	26.9
Oats . . .	870	20.6	4.8	6.8
Rice-meal . .	900	19.1	6.1	23.8
Wheat . . .	877	18.7	5.2	7.9
Rye . . .	857	17.6	5.8	8.5
Barley . . .	860	17.0	4.7	7.8
Maize . . .	890	16.6	3.7	5.7
Brewers' grains .	234	7.8	0.4	3.9
Clover-hay . .	840	19.7	18.6	5.6
Meadow-hay . .	857	15.5	16.0	4.3
Bean-straw . .	840	13.0	19.4	2.9
Oat-straw . .	857	6.4	16.3	2.8
Barley-straw . .	857	5.6	10.7	1.9
Wheat-straw . .	857	4.8	6.3	2.2
Potatoes . . .	250	3.4	5.8	1.6
Swedes . . .	107	2.2	2.0	0.6
Carrots . . .	140	2.1	3.0	1.1
Mangels . . .	120	1.8	4.6	0.7
Turnips . . .	80	1.6	2.9	0.8

NOTE VII. (p. 19).

Analyses of Stable-Manure, made respectively with Peat-moss Litter and Wheat-straw (by Bernard Dyer, B.Sc.)

	Peat-moss litter. Per cent.	Wheat-straw. Per cent.
Total nitrogen	0.88	0.61
Equal to ammonia . .	1.07	0.74
Phosphoric acid	0.37	0.43
Equal to Tribasic phosphate of lime (or Tricalcic phosphate)	0.80	0.94
Potash	1.02	0.59

NOTE VIII. (p. 19).

Analyses of Bracken (by J. Hughes, F.C.S.)

	No. 1. Young fern. Per cent.	No. 2. Old fern. Per cent.
Water	11.66	14.90
* Organic matter . . .	83.38	80.54
† Mineral matter . . .	4.96	4.56
	100.00	100.00
Containing—		
* Nitrogen	2.42	0.90
† Silica	1.60	2.81
Potash	1.15	0.10
Soda	0.64	0.26
Lime	0.44	0.62
Magnesia	0.13	0.47
Phosphoric acid . . .	0.60	0.30

NOTE IX. (p. 21).

Analyses of Horse-Manure.

For a fuller discussion of this question, the reader is referred to Heiden's 'Düngerlehre,' vol. ii. p. 185, and also to Storer's 'Agricultural Chemistry,' vol. i. p. 575.

The statements in the different text-books as to the quantity of manure produced by the horse are such as naturally to perplex the student. This discrepancy is due, however, to the different methods adopted by different writers of calculating this amount. The subject is further discussed in the footnote to p. 29. The following analyses of horse-manure may be valuable for reference. They are taken from Storer's 'Agricultural Chemistry,' vol. i. p. 496 :—

	1.	2.	3.	4.	5.	Average.
Water	75.76	69.30	67.23	72.13	71.30	71.15
Dry matter . .	24.24	24.82	32.72	27.87	28.70	27.67
Ash ingredients .	5.07	5.05	6.49	3.37	3.30	4.65
Potash	0.51	0.63	0.22	0.59	0.53	0.49
Lime	0.30	0.74	0.17	0.41	0.21	0.36
Magnesia . . .	0.19	0.29	0.20	0.17	0.14	0.20
Phosphoric acid .	0.41	0.67	0.35	0.12	0.28	0.36
Ammonia . . .	0.26	0.12	0.15	0.44	...	0.24
Total nitrogen .	0.53	0.69	0.47	0.67	0.58	0.59

NOTE X. (p. 24).

The Nature of the Chemical Reactions of Ammonia "Fixers."

For the student, the exact nature of the chemical reactions taking place may be of interest.

In the first place, it must be distinctly understood that the form in which ammonia escapes from the manure-heap is not, as is so commonly erroneously stated in agricultural text-books, as "free" ammonia. Whenever ammonia is brought into contact with carbonic acid, carbonate of ammonia is formed. When it is remembered that carbonic acid is by far the most abundant of the gaseous products of the decomposition of organic matter, it will be at once seen that free ammonia could not exist under such circumstances.

1. In the case of *hydrochloric acid*, the following chemical equation will represent the nature of the reaction—

$$2HCl + (NH_4)_2CO_3 = 2NH_4Cl + H_2O + CO_2$$

$2HCl$	$(NH_4)_2CO_3$	$2NH_4Cl$	H_2O+CO_2
(Hydrochloric acid,)	(carbonate of ammonia,)	(sal-ammoniac,)	(carbonic acid.)

2. In the case of *sulphuric acid*, the equation will be—

$$H_2SO_4 + (NH_4)_2CO_3 = (NH_4)_2SO_4 + H_2O + CO_2$$

H_2SO_4	$(NH_4)_2CO_3$	$(NH_4)_2SO_4$	H_2O+CO_2
(Sulphuric acid,)	(carbonate of ammonia,)	(sulphate of ammonia,)	(carbonic acid.)

3. With *gypsum* ($CaSO_4$)—

$$CaSO_4 + (NH_4)_2CO_3 = CaCO_3 + (NH_4)_2SO_4$$

$CaSO_4$	$(NH_4)_2CO_3$	$CaCO_3$	$(NH_4)_2SO_4$
(Gypsum,)	(carbonate of ammonia,)	(calcium carbonate,)	(sulphate of ammonia.)

4. With *copperas* ($FeSO_4$)—

$$FeSO_4 + (NH_4)_2CO_3 = FeCO_3 + (NH_4)_2SO_4$$

$FeSO_4$	$(NH_4)_2CO_3$	$FeCO_3$	$(NH_4)_2SO_4$
(Sulphate of iron,)	(carbonate of ammonia,)	(ferrous carbonate,)	(sulphate of ammonia.)

5. With *sulphate of magnesia* ($MgSO_4$)—

$$MgSO_4 + (NH_4)_2CO_3 = MgCO_3 + (NH_4)_2SO_4$$

$MgSO_4$	$(NH_4)_2CO_3$	$MgCO_3$	$(NH_4)_2SO_4$
(Sulphate of magnesia,)	(carbonate of ammonia,)	(carbonate of magnesia,)	(sulphate of ammonia.)

Reference has been made to the fact that magnesium sulphate may probably not only fix the ammonia, but the phosphoric acid. When magnesium sulphate, soluble phosphoric acid, and ammonia, are brought in contact with one another, the double insoluble phosphate of ammonium and magnesium ($MgNH_4PO_46Aq$) is formed. While such a reaction is possible, it is highly improbable that it takes place to any extent. The double phosphate is a crystalline salt which only separates after a considerable time, and in the presence of a large excess of ammonia.

NOTE XI. (p. 27).

ANALYSES OF COW-MANURE.[1]

	1.	2.	3.	4.	5.	6.	Average.
Water . . .	85.30	77.71	74.02	72.87	75.00	77.50	77.06
Dry matter . .	14.70	22.30	25.98	27.13	25.00	22.50	22.93
Ash ingredients	2.04	4.71	3.94	6.70	6.22	2.20	4.30
Potash . . .	0.36	0.46	0.56	1.69	0.39	0.40	0.64
Lime	0.29	0.37	0.58	0.41	0.24	0.31	0.48
Magnesia . .	0.19	0.11	0.13	...	0.18	0.11	...
Phosphoric acid	0.16	0.13	0.07	0.20	0.14	0.16	0.14
Ammonia . .	0.06	0.16	0.07	...	0.27	...	0.14
Total nitrogen .	0.38	0.54	0.41	0.79	0.46	0.34	0.48

NOTE XII. (p. 36).

COMPOSITION OF FRESH AND ROTTEN FARMYARD MANURE (VOELCKER).

Composition of fresh manure, composed of horse, cow, and pig dung, about fourteen days old :—

Water	66.17
* Soluble organic matter . . .	2.48
Soluble inorganic matter . .	1.54
† Insoluble organic matter . .	25.76
Insoluble inorganic matter . .	4.05
	100.00

* Containing nitrogen . . .	.149
Equal to ammonia . . .	.181
† Containing nitrogen . . .	.494
Equal to ammonia . . .	.599
Total percentage of nitrogen . .	.643
Equal to ammonia . . .	.780
Ammonia in a volatile state . .	.034
Ammonia in form of salts . .	.088

[1] Storer's Agricultural Chemistry, vol. i. p. 496.

Composition of the whole ash :—

Soluble in water, 27.55 per cent :—	
Soluble silica	4.25
Phosphate of lime	5.35
Lime	1.10
Magnesia	0.20
Potash	10.26
Soda	0.92
Chloride of sodium	0.54
Sulphuric acid	0.22
Carbonic acid and loss	4.71
Insoluble in water, 72.45 per cent :—	
Soluble silica	17.34
Insoluble silicious matter	10.04
Oxide of iron and alumina with phosphates	8.47
(Containing phosphoric acid, 3.18 per cent.)	
(Equal to bone-earth, 6.88 per cent.)	
Lime	20.21
Magnesia	2.56
Potash	1.78
Soda	0.38
Sulphuric acid	1.27
Carbonic acid and loss	10.40
	100.00

Composition of rotten dung, six months old, is as follows :—

Water	75.42
* Soluble organic matter	3.71
Soluble inorganic matter	1.47
† Insoluble organic matter	12.82
Insoluble inorganic matter	6.58
	100.00

* Containing nitrogen	.297
Equal to ammonia	.360
† Containing nitrogen	.309
Equal to ammonia	.375
Total amount of nitrogen	.606
Equal to ammonia	.735
Ammonia in a volatile state	.046
Ammonia in form of salts	.057

Composition of the whole ash :—

Soluble in water, 18.27 per cent :—	
Soluble silica	3.16
Phosphate of lime	4.75
Lime	1.44
Magnesia	0.59
Potash	5.58
Soda	0.29
Chloride of sodium	0.46
Sulphuric acid	0.72
Carbonic acid and loss	1.28
Insoluble in water, 81.73 per cent :—	
Soluble silica	17.69
Insoluble silica	12.54
Phosphate of lime	...
Oxides of iron alumina with phosphates	11.76
(Containing phosphoric acid, 3.40 per cent.)	
(Equal to bone-earth, 7.36 per cent.)	
Lime	20.70
Magnesia	1.17
Potash	0.56
Soda	0.47
Chloride of sodium	...
Sulphuric acid	0.79
Carbonic acid and loss	16.05
	100.00

NOTE XIII. (p. 39).

Comparison of Fresh and Rotten Manure (Wolff).

	Fresh.	Moderately rotten.
	(Taking the quantity of dry matter as the same.)	
Dry matter	25.00	25.00
Ash	3.81	4.76
Nitrogen	0.39	0.49
Potash	0.45	0.56
Lime	0.49	0.61
Magnesia	0.12	0.15
Phosphoric acid	0.18	0.23
Sulphuric acid	0.10	0.13
Silica	0.86	1.08

NOTE XIV. (p. 39).

LORD KINNAIRD'S EXPERIMENTS.[1]

"Lord Kinnaird has given the particulars of a very careful experiment. He tried to test the comparative value of manure kept in an open court with that kept under cover. He selected the same kind of cattle, gave them the same kind and quantity of food, and bedded them with the same kind of straw. A field of 20 acres of uniform land was selected. This having been equally divided, 2 acres out of each 10 gave the following results:—

Potatoes grown with Uncovered Manure.

	Tons.	cwt.	lb.
First measurement—1 acre produced .	7	6	8
Second do. do. do. .	7	18	99

Potatoes grown with Covered Manure.

	Tons.	cwt.	lb.
First measurement—1 acre produced .	11	17	56
Second do. do. do. .	11	12	26

This shows an increase of about 4 tons of potatoes per acre with the covered manure.

"The next year the weather was wet, grain soft and not in very good order, but the following was the amount of produce:—

Wheat grown with Uncovered Manure.

	Produce in grain.		Weight per bushel.	Produce in straw.		
Acre.	bushels.	lb.	lb.	stones.		lb.
First .	41	19	61½	152	of	22
Second .	42	38	61½	160	of	22

Wheat grown with Covered Manure.

First .	53	5	61	220	of	22
Second .	53	47	61	210	of	22"

[1] Scott's Manures and Manuring, p. 19.

NOTE XV. (p. 40).

Drainings of Manure-Heaps.

The importance of not separating the liquid portion from the solid portion has already been pointed out in dealing with the composition of the solid excreta and the urine. These two constituents of the manure are complementary to one another, and the value of farmyard manure as a general manure is very much impaired if the liquid portion is not applied along with the solid. In one important respect do the drainings of manure-heaps differ from urine—that is, in the percentage of phosphates they contain, the latter being practically devoid of phosphoric acid.

The following is an analysis of drainings from a manure-heap (Wolff):—

Dry substance	18.0	Magnesia	0.4
Ash	10.7	*Phosphoric acid*	0.1
Nitrogen	1.5	Sulphuric acid	0.7
Potash	4.9	Silica	0.2
Lime	0.3		

NOTE XVI. (p. 45).

Amounts of Potash and Phosphoric Acid removed by the following Rotations from a Prussian Morgen (.631 Acre).

	Potash. lb.	Phosphoric acid. lb.
1. Wheat	16.40	10.67
Oats	10.47	4.59
Potatoes	66.41	18.33
Hay	39.54	11.32
	132.82	44.81

The ratio of potash to phosphoric acid is 2.96 to 1.

	Potash. lb.	Phosphoric acid. lb.
2. Wheat	16.90	10.67
Barley	17.44	10.65
Potatoes	66.41	18.33
Hay	39.54	11.32
	140.29	50.97

The ratio of potash to phosphoric acid is 2.76 to 1.

	Potash. lb.	Phosphoric acid. lb.
3. Rye	20.03	12.15
Oats	10.97	4.59
Potatoes	66.41	18.33
Hay	39.54	11.32
	136.95	46.39

The ratio of potash to phosphoric acid is 2.95 to 1.

4. Wheat	16.90	10.67
Oats	10.97	4.59
Mangels	148.54	25.62
Hay	39.54	11.32
	215.95	52.20

The ratio of potash to phosphoric acid is 4.13 to 1.

5. Rye	20.03	12.15
Barley	17.44	10.65
Mangels	148.54	25.62
Hay	39.54	11.32
	225.55	59.74

The ratio of potash to phosphoric acid is 3.78 to 1.

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