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COMPOSITION AND DIGESTIBILITY OF CORN ENSILAGE, COW PEA ENSILAGE, SOJA BEAN ENSILAGE, AND CORN-FODDER.

[For explanations of technical terms and information concerning the uses of food constituents, the reader is referred to the Appendix.]

METHODS USED IN DIGESTION EXPERIMENTS.

The general method of conducting a digestion experiment is easily understood. The animal is fed a weighed amount of food, the composition of which is determined by analyzing a sample of it. Any part of the food which the animal does not eat is collected, weighed, and analyzed. By subtracting the amounts of the different nutrients in the refuse from the amounts fed, exactly what the animal has eaten is determined. Then by collecting, weighing, and analyzing the dung which is excreted and subtracting the amounts found from the amounts which were eaten, we learn what amount of each nutrient has been digested. By comparing the amount digested with the amount eaten we determine what per cent. of each nutrient has been digested. This per cent. is the digestion coefficient.

ANIMALS EMPLOYED.

Four high grade shorthorn steers, about two years old and 1,100 pounds average live weight, were selected with which to carry out the following experiments. Usually digestion experiments are made with not more than two animals, and often with only one. By using four animals it was expected (1) that any errors with the individual animals would be detected; (2) that, if there is a difference in the digestive powers of the different animals, it would become evident; and (3) that the results if satisfactory would be thoroughly trustworthy. The same four steers were used in each of the four experiments; that is, with corn ensilage, cow pea ensilage, soja bean ensilage, and corn-fodder. These steers were known in the records of the agricultural department as No. 53, No. 54, Roan, and No. 57, and they are so designated in this bulletin.

METHOD OF FEEDING.

In order to be sure that no other foods were in the alimentary canal the steers were fed during a preliminary period of one week on the same kind of food as that used in the experiment, care being taken that they obtained no trace of any other food; then the experiment proper was begun. The steers were fed regularly twice a day. For each feed a sufficient quantity was taken and thoroughly mixed. From this a sample was reserved and four separate portions were weighed out for the steers. The reserved samples were kept in tight vessels until the fourth feed had been given; then they were mixed together, placed in a meat chopper and cut fine, and from this a sample representing the average feed for two days was taken for analysis.

The steers were fed all they would eat reasonably clean. It was desired to learn the digestibility of the foods when eaten under these conditions, which correspond as nearly as it was possible to make them to the methods of feeding in ordinary practice by stock feeders. Often in digestion experiments the animals are given much less food than they would ordinarily eat, so little, in fact, that they eat all they receive, leaving no refuse whatever. Of course, this avoids the necessity of collecting and analyzing the refuse, but it is well known that with most coarse food-stuffs an animal must usually be kept in a half-starved condition to compel it to eat the food perfectly clean; and it is certainly questionable whether results obtained under such conditions fairly represent the digestibility of the food as ordinarily fed.

The refuse (uneaten food) from each steer was collected, and at the end of two days each steer's refuse was weighed, mixed, cut, and sampled for analysis.

COLLECTING THE DUNG.

Usually in digestion experiments the animals are made to wear continually a close-fitting harness by which a bag is held in position to catch the dung as it falls. In our experiments no harness was used. The steers were kept in Bidwell stalls without being tied. These stalls are adjustable in length by a movable box manger. The width allows the animal to lie down comfortably but not to turn around; and by a rope across the back end the animal is prevented from backing out of the stall. Just back of the hind feet was a drop of about six inches to receive the dung. The steers were bedded with sawdust, which was covered with matting tacked to the floor to keep it in place. The urine was absorbed by the sawdust, which was changed as often as necessary. Only every other stall was used; and, as the Bidwell stalls have one side made to swing open on a hinge, it was easy to change the sawdust and to keep the stalls in good order.

During the day the steers were attended almost constantly, and the dung was taken up from the drop at frequent intervals by means of a spatula and a small scoop and kept in covered vessels. During the night from about 10 o'clock p. m. till 5 o'clock a. m. the steers were left alone, but usually they lay quiet, and it was a common thing to find them at 5 a. m. still lying, and each with several pounds of dung in the drop which they had voided without rising. Great care was taken from the beginning to the end of the experiment that the drop should be kept clean from foreign matter and that no dung should be lost.

It may seem to some that it is not possible to let dung fall upon a clean, smooth floor and take it up again with a high degree of accuracy. Experiments were made to determine this. About 35 pounds of dung were allowed to fall in small quantities from a height of four feet, each being taken up before the next small quantity was allowed to fall. In two trials the average loss was one-fourth of an ounce. In three trials on 34 pounds of a different sample and on a different day the average loss was one-third of an ounce. The dung was then simply transferred from one vessel to another, about the same length of time being used as had been taken in the other trials, and it was found that the loss of weight by the evaporation of moisture was one-fourth of an ounce. Evidently this method of collecting the dung admits of a higher percentage of accuracy than many of the determinations in its subsequent analysis.

Experiments with cattle have shown that an average of about 24 hours is required for food to pass through the alimentary canal, although there are wide variations. In our experiments the collection of dung was commenced 24 hours after the beginning of the experiment, because it is evident that the composition of a sample of dung depends upon the composition of the food eaten the previous day rather than upon the composition of the food eaten at the time the dung is voided. While irregularities in voiding the dung may still introduce errors, yet if the experiment is carried on for a sufficient length of time, large amounts of material are collected and such possible errors become insignificant.

After the preliminary feeding the digestion experiments proper were begun, and continued for seven days; but the dung was not collected during the first day of the seven, and no analyses were made of the feed or refuse of the seventh day; thus the time actually corresponds to a period of six days. The importance of allowing time for the material to pass through the alimentary canal is evident (1) whenever the feed is not strictly uniform and it is necessary to take a sample of every feed for analysis, as, in fact, is usually done in digestion experiments; and (2) whenever the composition of the refuse is not uniform from day to day, for upon the composition of both feed and refuse depends the composition of the food eaten.

Methods of Analysis.

The fresh samples as brought from the barn were weighed and then reduced to the air-dry condition, first by drying the samples at about 50° C., and then allowing them to remain exposed to the air at the ordinary temperature till the weight became practically constant. They were then ground to pass through a millimeter sieve, placed in well stoppered bottles, and thoroughly mixed. The hygroscopic moisture was determined by drying a 2-gram sample in a current of dry hydrogen gas until the loss in weight became less than one milligram per hour. At the temperature of boiling water this required about 20 hours, but at 105° C. the same results were obtained in about one-third of that time. This temperature was obtained by using a reflux condenser, and an aqueous solution of glycerol instead of water.

The final analysis was made by the methods adopted by the Association of Official Agricultural Chemists (Bull. No. 43, U. S. Dep't of Agr., Div. of Chem.). The details of the methods were worked out and tested until a satisfactory degree of accuracy was obtained. All analyses were made in duplicate.

The ash was determined by burning to constant weight at a low red heat in a muffle furnace.

Kjeldahl's method was employed for the determination of nitrogen, and the protein was determined by multiplying the amount of nitrogen by the factor 6.25. The limit of error allowed in the nitrogen determination was one per cent. of the amount determined.

The fat was determined in the sample which had been dried in the determination of hygroscopic moisture. The substance to be extracted was placed in a glass cylinder whose bottom consisted of a piece of fat-free hardened filter paper, firmly tied over the lower end of the cylinder with wire. The cylinder was then placed in a Soxhlet extraction tube, and the fat extracted with absolute ether, which had been purified by distilling over a coil of wire made from metallic sodium, and had been kept over the same metal. The fat was filtered as it passed through the paper. The limit of error was reduced to below one milligram.

The fiber was determined in the fat-free sample by extraction with the 1.25 per cent. acid and alkaline solutions, the first filtration being made with Schleicher and Schüll's hardened filter paper, and the second with an asbestos filter. The limit of variation between duplicate determinations of fiber was kept below one per cent. of the amount determined.

Three composite samples of the feed were analyzed in each experiment, thus showing the average composition of the feed for three periods of two days each. This method shows any marked variation in the composition of the feed. Two composite samples were made of the refuse from each steer, one for a period of two days, and the other for a period of four days. The dung from each steer was also made into two composite samples, the first for two days and the second for a four days' period.

Daily records were kept throughout the experiments of the weights of the steers, the amounts of water drunk, and the temperature of the barn; but, as these records show no important connection with the questions under investigation, they are not published.

DIGESTIBILITY OF CORN ENSILAGE.

The digestibility of corn ensilage by cattle has been determined by three other experiment stations, and one of the reasons for choosing that food with which to begin these digestion experiments was to test the methods of work before taking up lines which had never been investigated. The feed was only a fair sample of corn ensilage made from several varieties of corn.

The essential data of the experiments are given in Tables 1 and 2.

NOTE.—The computations in these experiments and in those which follow were made chiefly by five place logarithms (checked by Thacher's calculating instrument), and because of this the final results are given with a higher degree of accuracy than they can be obtained by using the data here presented. For example, the per cent. of protein in the dry matter of the feed for Jan. 6th and

7th is given in Table I as 10.07, while the per cent. actually found was 10.065, and it was the logarithm of 10.065 which was used in making the computations. If 10.07 be used a slight discrepancy will appear, because a slight error will be introduced.

TABLE I. NUMBER OF POUNDS (BOTH FRESH AND DRY) OF CORN ENSILAGE FED, OF REFUSE, AND OF DUNG, FOR EACH STEER; AND ALSO THE PERCENTAGE COMPOSITION OF THE DRY MATTER.

	Date.	Amounts, pounds.		Composition of dry matter, percentages.				
	1895.	Fresh substance.	Dry matter	Ash.	Protein.	Fat.	Fiber.	Carbohydrate extract
			Steer No. 53.					
Feed	Jan. 2–3	148.00	37.423	6.58	9.92	2.90	22.92	57.68
Feed	Jan. 4–5	134.00	36.541	6.98	9.92	2.87	21.89	58.34
Feed	Jan. 6–7	125.00	36.287	8.07	10.07	2.70	22.21	56 95
Refuse	Jan. 2–3	22.13	4.288	5.98	9.66	1.04	28.12	55.20
Refuse	Jan. 4–7	49.83	10.039	6.79	9.54	.74	29.25	53.68
Dung	Jan. 3–4	77.81	11.923	13.04	12 73	1.71	25.57	46.95
Dung	Jan. 5–8	163.26	24.815	13.77	12.75	1.48	24.42	47.58
			Steer No. 54.					
Feed	Jan. 2–3	158.00	39.951	6.58	9.92	2.90	22.92	57.68
Feed	Jan. 4–5	137.00	37.359	6.98	9.92	2.87	21.89	58.34
Feed	Jan. 6–7	125.00	36.287	8.07	10.07	2.70	22.21	56.95
Refuse	Jan. 2–3	25.06	5.260	6.00	9.61	1.43	27.79	55.14
Refuse	Jan. 4–7	42.94	8.911	6.67	9.52	.79	29.36	53.66
Dung	Jan. 3–4	71.63	11.421	11.46	12.44	1.73	24.27	50.10
Dung	Jan. 5–8	157.87	26.421	12.89	12.85	1.70	23.38	49.18
			Steer Roan.					
Feed	Jan. 2–3	158.00	39.951	6.58	9.92	2.90	22.92	57.68
Feed	Jan. 4–5	138.00	37.633	6.98	9.92	2.87	21.89	58.34
Feed	Jan. 6–7	130.00	37.739	8.07	10.07	2.70	22.21	56.95
Refuse	Jan. 2–3	24.00	5.206	6.11	9.69	1.73	26.75	55.72
Refuse	Jan. 4–7	41.44	9.284	7.06	9.48	1.24	28.15	54.07
Dung	Jan. 3–4	90.57	13.268	11.77	11.70	1.59	25.90	49.04
Dung	Jan. 5–8	178 13	27.241	12.57	11.91	1.44	25.64	48.44
			Steer No. 57.					
Feed	Jan. 2–3	162.00	40.963	6.58	9.92	2.90	22.92	57.68
Feed	Jan. 4–5	142.00	38.724	6.98	9.92	2.87	21.89	58.34
Feed	Jan. 6–7	138.00	40.062	8.07	10.07	2.70	22 21	56.95
Refuse	Jan. 2–3	30.88	6.449	6.31	9.93	1.49	26.68	55.59
Refuse	Jan. 4–7	55.00	11.714	6.89	9.61	1.17	28.61	53.72
Dung	Jan. 3–4	77.56	12.205	12.75	12.15	1.73	24.38	48.99
Dung	Jan. 5–8	149 39	24.894	14.01	12.76	1.65	23.12	48.46

From the data given in Table I we are able to compute the digestion coefficients for each nutrient. Take, for example, the protein in the experiment with Steer No. 53. During the two days, Jan. 2d and 3d, Steer No. 53 was given 148 lb. of corn ensilage, but after subtracting the water it contained there remained 37.423 lb. of dry matter. Of this 37.423 lb. 9.92 per cent. was protein. By multiplying the number of pounds of dry matter by the per cent. of protein which it was found by analysis to contain, we have the number of pounds of protein fed to Steer No. 53 during the two days' period, Jan. 2d and 3d, and in like manner the amounts of protein fed during Jan. 4th and 5th, and during Jan. 6th and 7th are computed.

Thus:

	Dry matter, pounds.	Per cent. of protein.	Protein, pounds.
Jan. 2–3	37,423	9.92	3.712
Jan. 4–5	36,541	9.92	3.625
Jan. 6–7	36,287	10.07	3.652
Total protein fed during six days			10.989

In a similar way we find that the total amount of protein in the refuse during the six days' period, Jan. 2d to Jan. 7th, was 1.372 lb. By subtracting this from the amount of protein fed we find that 9.617 lb. of protein were eaten. Now by computation we find the amount of protein in the dung for the six days, Jan. 3d to Jan. 8th, was 4.682 lb.; and this subtracted from the amount eaten leaves 4.935 lb. of protein digested. Dividing the number of pounds of protein digested by 9.617, the number of pounds eaten, we have 51.32 per cent. of the total protein eaten. That is, 51.32 is the digestion coefficient of the protein as determined by Steer No. 53. The digestibility of each nutrient was determined by the same methods.

Table 2 gives the results in full for each steer for the six days' period.

TABLE 2. NUMBER OF POUNDS OF EACH NUTRIENT IN THE CORN ENSILAGE FED, IN THE REFUSE, AND IN THE DUNG, DURING A PERIOD OF SIX DAYS; AND ALSO THE DIGESTION COEFFICIENT OF EACH NUTRIENT.

	Dry matter.	Ash.	Protein.	Fat.	Fiber.	Carbo-hydrate extract.
Steer No. 53.						
Corn ensilage fed	110.251	7.940	10.989	3.110	24.636	63.576
Amounts refused	14.327	.938	1.372	.119	4.142	7.756
Amounts eaten	95.924	7.002	9.617	2.991	20.494	56.820
Dung excreted	36.738	4.972	4.682	.569	9.110	17.405
Amounts digested	59.186	2.030	4.935	2.422	11.384	39.415
Per cent. digested	**61.70**	**28.99**	**51.32**	**80.98**	**55.55**	**69.37**
Steer No. 54.						
Corn ensilage fed	113.597	8.164	11.321	3.207	25.385	65.520
Amounts refused	14.171	.910	1.353	.147	4.079	7.682
Amounts eaten	99.426	7.254	9.968	3.060	21.306	57.838
Dung excreted	37.842	4.716	4.816	.646	8.948	18.716
Amounts digested	61.584	2.538	5.152	2.414	12.358	39.122
Per cent. digested	**61.94**	**34.99**	**51.69**	**78.89**	**58.00**	**67.64**
Steer Roan.						
Corn ensilage fed	115.323	8.300	11.495	3.254	26.277	65.997
Amounts refused	14.490	.974	1.385	.205	4.006	7.920
Amounts eaten	100.833	7.326	10.110	3.049	22.271	58.077
Dung excreted	40.509	4.987	4.797	.604	10.420	19.701
Amounts digested	60.324	2.339	5.313	2.445	11.851	38.376
Per cent. digested	**59.83**	**31.93**	**52.55**	**80.19**	**53.21**	**66.08**
Steer No. 57.						
Corn ensilage fed	119.749	8.629	11.937	3.377	26.971	68.835
Amounts refused	18.163	1.214	1.766	.233	5.073	9.877
Amounts eaten	101.586	7.415	10.171	3.144	21.898	58.958
Dung excreted	37.099	5.043	4.660	.622	8.731	18.043
Amounts digested	64.487	2.372	5.511	2.522	13.167	40.915
Per cent. digested	**63.48**	**31.99**	**54.18**	**80.22**	**60.13**	**69.40**

In order to compare the digestibility of corn ensilage as determined at this station with the results obtained at other experiment stations the following table is published. This presents the results of all the experiments which have been made in the United States to determine the digestibility of corn ensilage by cattle.

The Pennsylvania Station has made 10 separate determinations, using five different samples of corn ensilage, the digestibility of each sample being determined with two animals as indicated in the table. Wisconsin has made two determinations, North Carolina one, and Illinois four, as given above.

Table 3 gives all of these determinations separately, and also the averages obtained from them.

TABLE 3. DIGESTIBILITY OF CORN ENSILAGE BY CATTLE, AS SHOWN BY ALL EXPERIMENTS MADE IN THE UNITED STATES.

Experiments made by:	Trial No.	Animals employed.	Dry matter	Ash.	Protein.	Fat.	Fiber.	Carbohydrate extract
Pennsylvania........	1	Steer No. 1..	72.1	30.7	60.4	89.7	79.6	72.1
Pennsylvania	2	Steer No. 2..	73.6	43.6	62.8	87.7	80.6	72.8
Pennsylvania........	3	Steer No. 1..	59.9	28.1	44.0	85.0	60.1	62.9
Pennsylvania	4	Steer No. 2..	66.7	40.3	47.9	87.0	67.0	70.0
Pennsylvania	5	Steer No. 1..	62.2	38.7	47.5	86.0	55.9	66.6
Pennsylvania	6	Steer No. 2..	60.5	18.7	43.5	86.4	55.6	66.2
Pennsylvania	7	Steer No. 1..	68.1	36.0	44.0	76.6	77.6	69.7
Pennsylvania	8	Steer No. 2..	60.4	18.6	32.4	74.7	71.6	59.8
Pennsylvania	9	Steer No. 1..	65.9	46.4	48.5	85.2	77.8	70.3
Pennsylvania	10	Steer No. 2..	66.2	39.7	45.0	83.7	72.7	66.1
Average of ten determinations			**65.6**	**34.1**	**47.6**	**84.2**	**69.9**	**67.7**
Wisconsin	1	Cow No. 1 ..	63.4	21.2	52.2	82.7	48.9	71.6
Wisconsin	2	Cow No 2 ..	62.9	18.2	55.3	82.1	45.4	71.8
Average of two determinations..........			**63.2**	**19.7**	**53.8**	**82.4**	**47.2**	**71.7**
North Carolina......	1	Cow........	**53.2**	**26.9**	**34.4**	**66.0**	**43.2**	**60.5**
Illinois	1	Steer No. 53.	61.7	29.0	51.3	81.0	55.6	69.4
Illinois	2	Steer No. 54.	61.9	35.0	51.7	78.9	58.0	67.6
Illinois.............	3	Steer Roan ..	59.8	31.9	52.6	80.2	53.2	66.1
Illinois.....	4	Steer No. 57.	63.5	32.0	54.2	80.2	60.1	69.4
Average of four determinations..........			**61.7**	**32.0**	**52.4**	**80.1**	**56.7**	**68.1**
Average of seventeen determinations.....			**63.6**	**31.5**	**48.6**	**81.9**	**62.6**	**67.8**

Evidently trials No. 1 and No. 2 by the Pennsylvania Station give results which are too high for the digestibility of corn ensilage, while the trial by the North Carolina Station gives results as much too low. Excluding these three determinations would slightly reduce most of the coefficients in the general average, and it would bring the average of the Pennsylvania Station considerably nearer to the general average.

The results obtained by the Illinois Station agree well among themselves and also with the general average. The coefficients for protein are somewhat above the average but they are almost identical with the Wisconsin determinations, and fall within the range of the results from the Pennsylvania Station. The Illinois coefficients for fiber are below the general average but they are nearer it than is the average from any other station.

DIGESTIBILITY OF COW PEA ENSILAGE.

The cow pea is a forage plant which is already attaining some prominence in Illinois. It is a leguminous plant, and, by means of the bacteria which inhabit its roots, it is enabled indirectly to draw upon the free nitrogen of the air for a part of its food supply.

In this respect it resembles clover, and it will prove of great value in improving the soil. Like clover, the cow pea plant is rich in protein, or nitrogenous matter, and this indicates that it may have a high feeding value for milk production and similar uses. In the form of ensilage it was readily eaten by the steers.

The data and the results obtained from the digestion experiments with cow pea ensilage are presented in Tables 4, 5, and 6.

TABLE 4. NUMBER OF POUNDS (BOTH FRESH AND DRY) OF COW PEA ENSILAGE FED, OF REFUSE, AND OF DUNG, FOR EACH STEER; AND ALSO THE PERCENTAGE COMPOSITION OF THE DRY MATTER.

	Date.	Amounts, pounds.		Composition of dry matter, percentages.				
	1895.	Fresh substance.	Dry matter	Ash.	Protein.	Fat.	Fiber.	Carbohydrate extract
				Steer No. 53.				
Feed	Jan. 29-30	176.00	37.030	11.21	15.29	2.99	27.99	42.52
Feed	Jan. 31-Feb. 1	174.00	38.352	11.09	14.51	2.66	27.43	44.31
Feed	Feb. 2-3.	168.00	35.366	11.13	15.42	3.02	27.64	42.79
Refuse	Jan. 29-30	10.50	2.316	7.67	10.45	.70	42.62	38.56
Refuse	Jan. 31-Feb. 3	38.06	7.535	8.13	9.89	.54	44.73	36.71
Dung	Jan. 30-31	68.47	13.968	19.44	16.45	2.86	30.85	30.40
Dung	Feb. 1-4	125.03	26.468	19.44	16.55	2.80	32.37	28.84
				Steer No. 54.				
Feed	Jan. 29-30	181.00	38.082	11.21	15.29	2.99	27.99	42.52
Feed	Jan. 31-Feb. 1	176.00	38.792	11.09	14.51	2.66	27.43	44.31
Feed	Feb. 2-3	173.00	36.419	11.13	15.42	3.02	27.64	42.79
Refuse	Jan. 29-30	3.63	.855	7.85	9.75	.79	38.91	42.70
Refuse	Jan. 31-Feb. 3	24.13	5.114	8.11	10.20	.60	42.32	38.77
Dung	Jan. 30-31	79.53	15.003	19.65	16.30	2.90	32.15	29.00
Dung	Feb. 1-4	147.85	28.464	19.36	16.46	2.76	31.01	30.41
				Steer Roan.				
Feed	Jan. 29-30	197.00	41.449	11.21	15.29	2.99	27.99	42.52
Feed	Jan. 31-Feb. 1	187.00	41.217	11.09	14.51	2.66	27.43	44.31
Feed	Feb. 2-3	171.00	35.998	11.13	15.42	3.02	27.64	42.79
Refuse	Jan. 29-30	15.25	3.520	7.64	10.44	.91	39.70	41.31
Refuse	Jan. 31-Feb. 3	36.78	8.188	7.73	10.09	.73	40.15	41.30
Dung	Jan. 30-31	87.25	15.910	19.64	15.90	2.80	32.21	29.45
Dung	Feb. 1-4	149.47	27.911	20.12	16.30	2.91	31.86	28.81
				Steer No. 57.				
Feed	Jan. 29-30	193.00	40.607	11.21	15.29	2.99	27.99	42.52
Feed	Jan. 31-Feb. 1	187.00	41.217	11.09	14.51	2.66	27.43	44.31
Feed	Feb. 2-3	174.00	36.629	11.13	15.42	3.02	27.64	42.79
Refuse	Jan. 29-30	10.25	2.336	8.08	10.20	.78	40.65	40.29
Refuse	Jan. 31-Feb. 3	47.41	10.383	7.88	9.92	.68	43.20	38.32
Dung	Jan. 30-31	76.53	14.839	19.91	16.27	2.70	29.59	31.53
Dung	Feb. 1-4	134.94	27.387	20.54	16.45	3.13	30.12	29.76

TABLE 5. NUMBER OF POUNDS OF EACH NUTRIENT IN THE COW PEA ENSILAGE FED, IN THE REFUSE, AND IN THE DUNG, FOR A PERIOD OF SIX DAYS, WITH EACH STEER; AND ALSO THE DIGESTION COEFFICIENTS OF EACH NUTRIENT.

	Dry matter.	Ash.	Protein.	Fat.	Fiber.	Carbo-hydrate extract.
Steer No. 53.						
Cow pea ensilage fed ..	110.748	12.350	16.678	3.194	30.659	47.867
Amounts refused......	9.851	.790	.987	.057	4.357	3.660
Amounts eaten........	100.897	11.560	15.691	3.137	26.302	44.207
Dung excreted.......	40.436	7.860	6.677	1.142	12.877	11.880
Amounts digested.....	60.461	3.700	9.014	1.995	13.425	32.327
Per cent. digested ...	**59.92**	**32.01**	**57.45**	**63.60**	**51.04**	**73.13**
Steer No. 54.						
Cow pea ensilage fed ..	113.293	12.635	17.064	3.268	31.364	48 962
Amounts refused......	5.969	.482	.605	.038	2.497	2.347
Amounts eaten........	107.324	12.153	16.459	3.230	28.867	46.615
Dung excreted........	43.467	8.457	7.129	1.220	13.652	13.009
Amounts digested.....	63.857	3.696	9.330	2.010	15.215	33.606
Per cent. digested ...	**59.50**	**30.41**	**56.69**	**62.23**	**52.71**	**72.09**
Steer Roan.						
Cow pea ensilage fed...	118.664	13.234	17.867	3.421	32.855	51.287
Amounts refused......	11.708	.902	1.193	.092	4.686	4.835
Amounts eaten........	106.956	12.332	16.674	3.329	28.169	46.452
Dung excreted........	43.821	8.741	7.081	1.257	14.017	12.725
Amounts digested.....	63.135	3.591	9.593	2.072	14.152	33.727
Per cent. digested ...	**59.03**	**29.12**	**57.53**	**62.24**	**50.24**	**72.61**
Steer No. 57.						
Cow pea ensilage fed ..	118.453	13.210	17.835	3.415	32.793	51.200
Amounts refused......	12.719	1.008	1.268	.088	5.434	4.921
Amounts eaten........	105.734	12.202	16.567	3.327	27.359	46.279
Dung excreted........	42.226	8.579	6.918	1.257	12.639	12.833
Amounts digested......	63.508	3.623	9.649	2.070	14.720	33.446
Per cent. digested ...	**60.06**	**29.69**	**58.24**	**62.22**	**53.80**	**72.27**

TABLE 6. DIGESTION COEFFICIENTS FOR COW PEA ENSILAGE AS OBTAINED FROM EACH STEER, AND ALSO THE AVERAGE OF THE FOUR DETERMINATIONS.

Animals employed.	Dry matter.	Ash.	Protein.	Fat.	Fiber.	Carbo-hydrate extract.
Steer No. 53..........	59.9	32.0	57.5	63.6	51.0	73.1
Steer No. 54..........	59.5	30.4	56.7	62.2	52.7	72.1
Steer Roan...........	59.0	29.1	57.5	62.2	50.2	72.6
Steer No. 57..........	60.1	29.7	58.2	62.2	53.8	72.3
Average of four.....	**59.6**	**30.3**	**57.5**	**62.6**	**52.0**	**72.5**

These determinations agree well and the results are very satisfactory. The average of the four determinations is given in

Table 17, page 205. By referring to that table and comparing these results with the digestibility of clover hay it will be found that the total dry matter of the cow pea ensilage is about 7 per cent. more digestible than that of clover hay, and the protein is 6 per cent., the fat 15 per cent., the fiber 5 per cent., and the carbohydrate extract 13 per cent. more digestible. It should be noted that the digestibility of clover hay was determined with sheep, although it may also be stated that most authorities agree that cattle and sheep have equal digestive powers, and most tables of digestion coefficients are given for ruminants, no distinction being made.

In Table 18, page 205, both composition and digestibility are considered, and it is shown that 100 lb. of the dry matter of cow pea ensilage furnishes 8 lb. of protein and 13,000 calories of energy above that furnished by 100 lb. of dry matter of clover hay.

No other determinations of the digestibility of cow pea ensilage have been made in the United States, nor in other countries, so far as I have been able to learn.

DIGESTIBILITY OF SOJA BEAN ENSILAGE.

The soja bean is a leguminous plant, which has been introduced into this country from Japan. Like clover, it is a "nitrogen gatherer," and it contains a high percentage of protein. It has already been grown as a forage plant to some extent in the United States.

The data and results obtained from the digestion experiments with soja bean ensilage are given in Tables 7, 8, and 9.

TABLE 7. NUMBER OF POUNDS (BOTH FRESH AND DRY) OF SOJA BEAN ENSILAGE FED, OF REFUSE, AND OF DUNG, FOR EACH STEER; AND ALSO THE PERCENTAGE COMPOSITION OF THE DRY MATTER.

	Date.	Amounts, pounds.		Composition of dry matter, percentages.				
	1895.	Fresh substance.	Dry matter	Ash.	Protein.	Fat.	Fiber.	Carbohydrate extract
				Steer No. 53.				
Feed	Feb. 19–20	131.00	31.714	12.61	11.49	2.83	33.89	39.18
Feed	Feb. 21–22	130.00	31.746	15.87	13.21	3.15	30.26	37.51
Feed	Feb. 23–24	125.00	30.412	14.31	13.94	3.40	29.02	39.33
Refuse	Feb. 19–20	17.16	4.843	7.26	6.56	.82	51.27	34.09
Refuse	Feb. 21–24	32.97	9.262	8.15	7.63	.90	50.60	32.72
Dung	Feb. 20–21	60.03	12.828	19.99	13.04	3.82	32.48	30.67
Dung	Feb. 22–25	127.97	27.224	23.41	12.06	3.68	29.89	30.96
				Steer No. 54.				
Feed	Feb. 19–20	138.00	33.408	12.61	11.49	2.83	33.89	39.18
Feed	Feb. 21–22	129.00	31.502	15.87	13.21	3.15	30.26	37.51
Feed	Feb. 23–24	103.00	25.061	14.31	13.94	3.40	29.02	39.33
Refuse	Feb. 19–20	17.88	4.942	7.85	7.00	.92	50.76	33.47
Refuse	Feb. 21–24	32.82	9.046	8.07	8.02	1.04	49.62	33.25
Dung	Feb. 20–21	71.81	13.301	19.27	12.52	3.55	33.66	31.00
Dung	Feb. 22–25	133.50	24.814	22.91	12.13	3.59	31.21	30.16
				Steer, Roan.				
Feed	Feb. 19–20	138.00	33.408	12.61	11.49	2.83	33.89	39.18
Feed	Feb. 21–22	137.00	33.455	15.87	13.21	3.15	30.26	37.51
Feed	Feb. 23–24	123.00	29.927	14.31	13.94	3.40	29.02	39.33
Refuse	Feb. 19–20	17.56	5.030	7.02	6.34	.66	53.99	31.99
Refuse	Feb. 21–24	32.19	9.151	7.61	7.74	.97	50.13	33.55
Dung	Feb. 20–21	72.53	12.973	20.55	13.25	3.61	32.25	30.34
Dung	Feb. 22–25	147.19	28.819	22.85	11.93	3.63	31.38	30.21
				Steer No. 57.				
Feed	Feb. 19–20	102.00	24.693	12.61	11.49	2.83	33.89	39.18
Feed	Feb. 21–22	86.00	21.001	15.87	13.21	3.15	30.26	37.51
Feed	Feb. 23–24	101.00	24.573	14.31	13.94	3.40	29.02	39.33
Refuse	Feb. 19–20	13.09	3.680	7.00	6.58	.74	52.00	33.68
Refuse	Feb. 21–24	15.47	4.546	6.71	6.55	.67	53.73	32.34
Dung	Feb. 20–21	50.78	10.440	20.09	12.43	3.32	33.38	30.78
Dung	Feb. 22–25	111.29	20.531	22.88	11.80	3.26	31.48	30.58

TABLE 8. NUMBER OF POUNDS OF EACH NUTRIENT IN THE SOJA BEAN ENSILAGE FED, IN THE REFUSE, AND IN THE DUNG, DURING A PERIOD OF SIX DAYS; AND ALSO THE DIGESTION COEFFICIENTS.

	Dry matter.	Ash.	Protein.	Fat.	Fiber.	Carbo-hydrate extract.
			Steer No. 53.			
Soja bean ensilage fed..	93.872	13.392	12.079	2.930	29.182	36.289
Amounts refused......	14.105	1.107	1.025	.123	7.169	4.681
Amounts eaten........	79.767	12.285	11.054	2.807	22.013	31.608
Dung excreted.......	40.052	8.939	4.957	1.491	12.303	12.362
Amounts digested......	39.715	3.346	6.097	1.316	9.710	19.246
Per cent. digested....	**49.79**	**27.24**	**55.16**	**46.88**	**44.11**	**60.89**
			Steer No. 54.			
Soja bean ensilage fed..	89.971	12.801	11.495	2.789	28.129	34.757
Amounts refused......	13.988	1.118	1.071	.140	6.996	4.663
Amounts eaten	75.983	11.683	10.424	2.649	21.133	30.094
Dung excreted........	38.115	8.249	4.675	1.364	12.222	11.605
Amounts digested	37.868	3.434	5.749	1.285	8.911	18.489
Per cent. digested....	**49.84**	**29 39**	**55.15**	**48.51**	**42.17**	**61.44**
			Steer Roan.			
Soja bean ensilage fed..	96.790	13.807	12.432	3.016	30.132	37.403
Amounts refused......	14.181	1.049	1.027	.122	7.302	4.681
Amounts eaten	82.609	12.758	11.405	2.894	22.830	32.722
Dung excreted........	41.792	9.250	5.158	1.514	13.227	12.643
Amounts digested.....	40.817	3.508	6.247	1.380	9.603	20.079
Per cent. digested ...	**49.41**	**27 50**	**54.77**	**47.68**	**42.06**	**61 36**
			Steer No. 57.			
Soja bean ensilage fed..	70.267	9.965	9.038	2.196	21.856	27.212
Amounts refused......	8.226	.563	.540	.058	4.356	2.709
Amounts eaten........	62.041	9.402	8.498	2.138	17.500	24.503
Dung excreted	30.971	6.795	3.720	1.016	9.948	9.492
Amounts digested	31.070	2.607	4.778	1.122	7.552	15.011
Per cent. digested ...	**50.08**	**27.73**	**56.23**	**52.48**	**43.15**	**61.26**

TABLE 9. DIGESTION COEFFICIENTS FOR SOJA BEAN ENSILAGE AS OBTAINED FROM EACH STEER, AND ALSO THE AVERAGE OF THE FOUR DETERMINATIONS.

Animals employed.	Dry matter.	Ash	Protein.	Fat.	Fiber.	Carbo-hydrate extract.
Steer No. 53..........	49.8	27.2	55.2	46 9	44.1	60.9
Steer No. 54..........	49.8	29.4	55.2	48.5	42.2	61.4
Steer Roan...........	49.4	27.5	54.8	47.7	42.1	61.4
Steer No. 57..........	50.1	27 7	56.2	52.5	43.2	61.3
Average of four.....	**49.8**	**28.0**	**55.3**	**48.9**	**42.9**	**61 2**

The only other determinations which have been made of the digestibility of soja bean ensilage are those reported by the North

Carolina Station in Bulletin No. 87d. The determinations were made with goats, and the results of the experiments are given below:

Animals employed.	Dry matter.	Ash.	Protein.	Fat.	Fiber.	Carbo-hydrate extract.
Goat No. 1............	52.3	47.1	71.3	66.4	47.1	45.9
Goat No. 2............	65.8	66.3	80.2	77.3	62.5	58.2

From these results it appears that goats are able to digest a higher per cent. of soja bean ensilage than cattle; but the wide differences shown in the determinations with the goats indicate that such an assumption may not be trustworthy.

The average of the results obtained from the four steers is given in Table 17, page 205, by referring to which it will be seen that the digestibility of soja bean ensilage corresponds closely to that of clover hay, being somewhat lower for dry matter and fiber, but slightly higher for protein, fat, and carbohydrate extract. Table 17 also shows that the digestibility of soja bean ensilage is considerably lower than that of cow pea ensilage. It was found in conducting the experiments that the ensilage from soja beans was eaten by the steers much less readily than that from cow peas; and the data given show that smaller amounts of dry matter of the soja beans were eaten.

DIGESTIBILITY OF CORN-FODDER.

By corn-fodder is meant the entire corn plant as cut, the ears not having been removed. That used in these experiments was a good quality of corn-fodder. On being put into the barn it had been run through a machine by which it was cut into short pieces, but not shredded. Thus it consisted of short pieces of stalk together with the light leaves and husks, heavy short pieces of ears of corn and some shelled corn. It was exceedingly difficult to obtain portions for feeding and for analysis which would represent even a close approximation to uniformity. Much care was taken, however, to obtain results which should be as nearly exact as possible with the methods employed, and the amount of error which may have been introduced by imperfect sampling will be shown later.

As might be expected, the corn-fodder was not eaten by the steers as freely as the corn ensilage had been. Of course, this would be the case with the fresh substance, but it was also found that on the basis of dry matter a smaller amount of corn-fodder than of corn ensilage was eaten. This fact was especially noticeable with Steer No. 53.

The data and the results obtained in the experiments with corn-fodder are given in Tables 10 and 11, and Table 12 gives for comparison the results of all determinations made in the United States.

TABLE 10. NUMBER OF POUNDS (BOTH FRESH AND DRY) OF CORN-FODDER FED, OF REFUSE, AND OF DUNG, FOR EACH STEER; AND ALSO THE PERCENTAGE COMPOSITION OF THE DRY MATTER.

	Date.	Amounts, pounds.		Composition of dry matter, percentages.				
	1895.	Fresh substance.	Dry matter	Ash.	Protein.	Fat.	Fiber.	Carbohydrate extract
			Steer No. 53.					
Feed	Mar. 22–23	27.00	22.503	4.92	6.99	1.91	23.09	63.09
Feed	Mar. 24–25	12.00	9.992	4.37	7.28	2.18	21.39	64.78
Feed	Mar. 26–27	24.00	20.804	4.36	6.76	2.02	23.77	63.09
Refuse	Mar. 22–23	10.19	8.524	5.30	5.06	.98	32.37	56.29
Refuse	Mar. 24–27	4.75	3.978	4.77	4.63	1.00	33.89	55.71
Dung	Mar. 23–24	23.75	4.426	8.86	13.86	1.71	16.80	58.77
Dung	Mar. 25–28	53.91	9.418	10.45	12.68	1.45	20.15	55.27
			Steer No. 54.					
Feed	Mar. 22–23	44.00	36.669	4.92	6.99	1.91	23.09	63.09
Feed	Mar. 24–25	32.00	26.644	4.37	7.28	2.18	21.39	64.78
Feed	Mar. 26–27	30.00	26.005	4.36	6.76	2.02	23.77	63.09
Refuse	Mar. 22–23	11.78	7.921	4.28	4.51	.93	34.75	55.53
Refuse	Mar. 24–27	10.31	8.463	3.55	3.67	.68	34.87	57.23
Dung	Mar. 23–24	53.72	11.523	8.32	12.55	2.35	15.36	61.42
Dung	Mar. 25–28	88.15	18.986	9.29	12.84	1.69	16.10	60.08
			Steer, Roan.					
Feed	Mar. 22–23	43.00	35.838	4.92	6.99	1.91	23.09	63.09
Feed	Mar. 24–25	33.00	27.477	4.37	7.28	2.18	21.39	64.78
Feed	Mar. 26–27	28 00	24.271	4.36	6.76	2.02	23.77	63.09
Refuse	Mar. 22–23	9.32	7.563	4.40	4.39	.92	34.16	56.13
Refuse	Mar. 24–27	8.28	6.973	4.27	4.32	1.01	34.98	55.42
Dung	Mar. 23–24	61.38	12.219	9.05	11.68	1.45	18 49	59.33
Dung	Mar. 25–28	94.60	19.191	9.41	11.22	1 38	18.18	59.81
			Steer No. 57.					
Feed	Mar. 22–23	46.00	38.338	4.92	6.99	1.91	23.09	63.09
Feed	Mar. 24–25	38.00	31.639	4.37	7.28	2.18	21.39	64.78
Feed	Mar. 26–27	37.00	32.073	4.36	6.76	2.02	23 77	63.09
Refuse	Mar. 22–23	9.78	7.841	3.19	3.46	.72	35.18	57.45
Refuse	Mar. 24–27	12.66	10.224	2.94	3.36	.69	36.16	56.85
Dung	Mar. 23–24	62.44	10.463	11.73	13.49	1.68	17.94	55.16
Dung	Mar. 25–28	110.45	19.134	11.17	12.48	1.65	18.29	56.41

TABLE II. NUMBER OF POUNDS OF EACH NUTRIENT IN THE CORN-FODDER FED, IN THE REFUSE AND IN THE DUNG, DURING A PERIOD OF SIX DAYS; AND ALSO THE DIGESTION COEFFICIENTS.

	Dry matter.	Ash.	Protein.	Fat.	Fiber.	Carbohydrate extract.
Steer No. 53.						
Corn-fodder fed	53.299	2.452	3.706	1.067	12.279	33.795
Amounts refused	12.502	.642	.615	.123	4.107	7.015
Amounts eaten	40.797	1.810	3.091	.944	8.172	26.780
Dung excreted	13.844	1.376	1.807	.213	2.641	7.807
Amounts digested	26.953	.434	1.284	.731	5.531	18.973
Per cent. digested	**66.07**	**23.98**	**41.54**	**77.44**	**67.68**	**70.85**
Steer No. 54.						
Corn-fodder fed	89.318	4.103	6.260	1.806	20.349	56.800
Amounts refused	16.384	.640	.668	.131	5.704	9.241
Amounts eaten	72.934	34.63	5.592	1.675	14.645	47.559
Dung excreted	30.509	27.23	3.887	.592	4.827	18.480
Amounts digested	42.425	.740	1.705	1.083	9.818	29.079
Per cent. digested	**58.17**	**21.37**	**30.49**	**64.66**	**67.04**	**61.16**
Steer Roan.						
Corn-fodder fed	87.586	4.022	6.145	1.773	19.922	55.724
Amounts refused	14.536	.631	.633	.140	5.023	8.109
Amounts eaten	73.050	3.391	5.512	1.633	14.899	47.615
Dung excreted	31.410	2.913	3.580	.443	5.749	18.725
Amounts digested	41.640	.478	1.932	1.190	9.150	28.890
Per cent. digested	**57.00**	**14.10**	**35.05**	**72.87**	**61.41**	**60.67**
Steer No. 57.						
Corn-fodder fed	102.050	4.668	7.151	2.070	23.244	64.917
Amounts refused	18.065	.551	.615	.127	6.457	10.315
Amounts eaten	83.985	4.117	6.536	1.943	16.787	54.602
Dung excreted	29.597	3.365	3.800	.493	5.378	16.561
Amounts digested	54.388	.752	2.736	1.450	11.409	38.041
Per cent. digested	**64.76**	**18.27**	**41.86**	**74.63**	**67.96**	**69.67**

TABLE 12. DIGESTIBILITY OF CORN-FODDER BY CATTLE, AS SHOWN BY ALL EXPERIMENTS MADE IN THE UNITED STATES.

Experiments made by	Trial No.	Animals employed.	Dry matter	Ash.	Pro-tein.	Fat.	Fiber.	Car-bohy-drate ex-tract.
Pennsylvania........	1	Steer No. 1..	67.1	32.3	55.7	76.8	76.0	66.5
Pennsylvania	2	Steer No. 2..	67.7	42.9	61.5	81.6	72.9	67.2
Pennsylvania........	3	Steer No. 1..	68.8	51.0	46.6	80.0	73.1	70.3
Pennsylvania........	4	Steer No. 2..	64.2	46.8	40.7	78.7	69.3	65.0
Pennsylvania........	5	Steer No. 1..	63.9	25.6	36.0	84.2	74.3	65.6
Pennsylvania........	6	Steer No. 2..	57.6	9.9	22.4	65.7	66.7	59.9
Average of six determinations.........			**64.9**	**34.7**	**43.8**	**77.8**	**72.1**	**65.8**
Wisconsin...........	1	Cow No. 1...	58.8	14.9	46.4	66.7	53.4	64.0
Wisconsin...........	2	Cow No. 2...	60.9	23.2	51.2	70.4	58.9	66.0
Average of two determinations........			**59.9**	**19.1**	**48.8**	**68.6**	**56.2**	**65.0**
Illinois.............	1	Steer No. 53.	66.1	24.0	41.5	77.4	67.7	70.9
Illinois.............	2	Steer No. 54.	57.2	21.4	30.5	64.7	67.0	61.2
Illinois.............	3	Steer Roan..	58.0	14.1	35.1	72.9	61.4	60.7
Illinois.............	4	Steer No. 57.	64.8	18.3	41.9	74.6	68.0	69.7
Average of four determinations........			**61.5**	**19.4**	**37.2**	**72.4**	**66.0**	**65.6**
Average of twelve determinations.....			**62.9**	**27.0**	**42.4**	**74.5**	**67.4**	**65.7**

Although the average of our results from the experiments with corn-fodder agrees well with the general average of all American experiments, and the individual variations are no wider than are commonly reported from digestion experiments, yet they are not satisfactory, because they are not more nearly exact; and the evidence of our other digestion experiments proves that the digestibility of foods can be determined with a much higher degree of accuracy than is shown by the results from corn-fodder.

A careful attempt has been made to locate the source of error in these experiments. As already mentioned, it was extremely difficult to obtain fair samples of the corn-fodder. This difficulty was anticipated, and in order to determine the influence of an error which might be introduced from that source a check sample was taken of every portion of feed, refuse, and dung sampled for analysis. Then the percentage of total dry matter in these check samples was determined. This furnishes data for a second determination of the digestibility of the dry matter entirely independent of the samples and analyses of the former determination. For comparison both determinations are given below:

TABLE 13. DIGESTION COEFFICIENTS FOR DRY MATTER OF CORN-FODDER.

	Steer No. 53.	Steer No. 54.	Steer Roan.	Steer No. 57.	Average.
First determination.............	66.1	58.2	57.0	64.8	61.5
Second determination............	66.2	59.0	58.4	65.2	62.2
Total variation..............	.1	.8	1.4	.4	.7

This shows a maximum variation of 1.4 per cent. with Roan, and a minimum of .1 per cent. with No. 53. The average variation is .7 per cent. Certainly the error due to imperfect sampling is very small and does not account for the variation of nearly 10 per cent. between different animals.

It has already been pointed out that irregularities in voiding the dung might introduce an error in the result. In order to determine the possible influence of such an error the digestion coefficients were determined for a period of four days' feeding as well as for the full period of six days. Both determinations are given below:

TABLE 14. DIGESTION COEFFICIENTS FOR DRY MATTER OF CORN-FODDER.

	Steer No. 53.	Steer No. 54.	Steer Roan.	Steer No. 57.	Average.
From six days' period...........	66.1	58.2	57.0	64.8	61.5
From four days' period..........	64.9	57.0	57.1	64.2	60.8
Total variation.............	1.2	1.2	.1	.6	.7

It is well understood that four days' time is too short a period to be relied upon in determining digestion coefficients, but even by using the data obtained in four days we have only an average variation of .7 per cent. with a maximum of 1.2 per cent. from the coefficients for dry matter obtained in the six days' period. Evidently the wide variation between the animals is not due to irregularities in voiding the dung.

There seems to be no alternative but to conclude that the variations are due to the individuality of the animals themselves. By taking a general view of the results obtained from all the experiments, including those with corn ensilage, cow pea ensilage, soja bean ensilage, and corn-fodder, this animal individuality becomes more evident. The following table gives for comparison the digestibilty of the dry matter of each of the four food-stuffs:

TABLE 15. DIGESTION COEFFICIENTS FOR TOTAL DRY MATTER, SHOWING ANIMAL INDIVIDUALITY.

Food-stuff.	Steer No. 53.	Steer No. 54.	Steer Roan.	Steer No. 57.	Average.
Corn ensilage..................	61.7	61.9	59.8	63.5	61.7
Cow pea ensilage...............	59.9	59.5	59.0	60.1	59.6
Soja bean ensilage.............	49.8	49.8	49.4	50.1	49.8
Corn-fodder....................	66.1	58.2	57.0	64.8	61.5

The result obtained from Steer No. 53 with corn-fodder should be omitted in the comparison, owing to the fact that he ate only about one-half as much of that food as the other animals, as may be seen from Table 10. It is highly probable that the effect of eating such a small amount of food would be easily to destroy the animal individuality in that case. This single result being disregarded it will be seen that No. 53 and No. 54 gave results which are markedly uniform, that in every case Roan gave the lowest result and No. 57 the highest.

There are two possible sources of this animal individuality—first, in the process of mastication; and, second, in the action of the digestive fluids. That it is at least chiefly due to the first of these sources seems evident from a further study of Table 15. With those foods which would seem to require the least effort in mastication, as cow pea ensilage and soja bean ensilage, the individuality is the least marked, but it becomes more apparent with the corn ensilage, which contains the whole kernels of corn, and it is most prominent with the corn-fodder, which contains the whole kernels in a dry and hard condition. This view of the source of this animal individuality is strengthened by the fact that kernels of corn which escape mastication, pass through the alimentary canal, and are excreted with the dung have practically the same composition before and after passing through the animal, indicating that if the kernels are not ground or broken the digestive fluids have little or no action upon them. By referring to the results obtained, as given in Table 12, we see that the low digestibility of the dry matter of corn-fodder as determined by Steers No. 54 and Roan is mainly found in the protein and carbohydrate extract, and then by turning to Table 16 it will be seen that these two substances constitute more than 90 per cent. of the total dry matter of shelled corn, but less than 60 per cent. of dry corn stover.

This subject is receiving further consideration.

METABOLIC PRODUCTS.

By metabolic products is meant those animal products resulting from the use, wear, or waste of the animal tissues or fluids. Some of these products, coming from the wear of the alimentary canal, from the digestive fluids, etc., are thrown off with the dung. Attempts have been made by different German and American experimenters to determine the amount of some of these metabolic products contained in the dung, but the results so far obtained are neither concordant nor conclusive. When our knowledge concerning these products shall have become exact and trustworthy, it is probable that the amount of these metabolic products will be subtracted from the amount of dung in order to determine the exact amount that is truly indigestible food, although in calculating only the comparative value of foods it may never be necessary.

It may be stated that one who is familiar with the work of Stutzer, Pfeiffer, Prof. Jordan, Dr. Gustav Kühn, and others, along the lines of metabolic products and natural and artificial digestion, is forced to the conclusion that our present knowledge does not enable us to apply corrections to animal digestion for metabolic products with any satisfactory degree of assurance of accuracy.

SUMMARY.

The composition of cow pea ensilage corresponds very closely to that of clover hay, the most important difference being in the higher percentage of fat found in the clover, but the digestibility of the cow pea ensilage is so much greater that it furnishes an equal amount of fat and much more protein and total energy than the clover hay.

Soja bean ensilage resembles clover hay both in composition and digestibility. It furnishes an equal amount of protein, more fat, but less total energy than clover hay.

Both of these leguminous forage plants draw upon the free nitrogen of the air in an indirect way for a part of their food supply; their composition shows a high percentage of nitrogen ; and they have great value for improving the soil.

Corn-fodder and corn ensilage have about the same digestibility for total dry matter and furnish nearly equal amounts of energy. The fodder furnishes more digestible carbohydrate extract, but the ensilage slightly more of the other nutrients.

As compared with cow peas and soja beans, the corn-fodder and corn ensilage have a much higher value for energy or fat production, but the cow pea ensilage and soja bean ensilage are far more valuable for animal growth or the production of milk.

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APPENDIX.

CONSTITUENTS AND USES OF FOOD.

The value of palatable food depends largely upon two things—its composition and its digestibility. The composition is determined by chemical analysis, which shows the different substances the food contains, and also the amount, or per cent., of each substance. By the digestibility we mean the per cent. digested of the food which is eaten by the animal, and not only the per cent. of the total food eaten but also the per cent. of each substance or group of substances which the food contains. The digestibility of food is determined by actual trial with animals.

Composition of Foods.

Most plants are composed of thirteen simple, primary substances which are called elements. An element is a substance which cannot be divided by any known means into two different substances. Iron is an element, because pure iron contains nothing but iron, and it cannot be separated into anything but iron. Sulfur and carbon are also elements. Some elements exist in the form of gas ; such are the elements oxygen and nitrogen, of which the air is chiefly composed.

A *compound* is composed of two or more elements which are united in such a way that the elements themselves are not easily recognized. Water is a compound of the two elements oxygen and hydrogen, both of which are gases; and sugar is a compound of these two elements and the element carbon. If sugar is heated the elements oxygen and hydrogen are driven off, mainly in the form of water, or steam, and only the black carbon remains. If the heat is continued this carbon, or charcoal, may unite with the element oxygen of the air and form the compound carbon dioxid, which is a gas.

The name of any simple compound will usually show just what elements the compound contains. Iron sulfid is a compound of iron and sulfur. Iron oxid contains iron and oxygen; carbon dioxid (*di* meaning *two*) contains carbon and oxygen; carbon disulfid, carbon and sulfur ; and sodium chlorid (common salt) is composed of the elements sodium and chlorin.

There are four of the thirteen elements of which plants are composed that are of especial importance :

1. *Carbon.* This solid element is well represented by soot or lamp black. Ordinary charcoal is chiefly carbon ; and charcoal made from pure sugar or starch is pure carbon. Coal is also mainly carbon. All kinds of *carbon*ates, of course, contain *carbon.*

2. *Hydrogen.* This element is a gas when not combined with other elements. It is the lightest of all known substances. When hydrogen burns it unites with the oxygen of the air and forms the compound which we call *water.*

3. *Oxygen.* About one-fifth of the air consists of oxygen in the free, or uncombined, state; and eight-ninths of water is oxygen. Generally compounds whose scientific names end in *-ate* contain oxygen, and all oxids contain oxygen.

4. *Nitrogen.* This element constitutes about four-fifths of the air. It is contained in all kinds of nitrates, as potassium nitrate (saltpeter). Ammonia is a compound of nitrogen and hydrogen. Nitrogen is one of the valuable elements of commercial fertilizers.

These four elements, carbon, hydrogen, oxygen, and nitrogen, constitute what is called *organic matter.* All that plants contain besides this organic matter and water is what remains as ash when the plants are burned.

It should be noted that in the higher forms of life there is an important difference between plants and animals in regard to the sources of their food materials. The plant for its supplies draws upon the elements, usually in the form of very simple compounds, such as water, carbon dioxid, ammonia, etc. The plant takes these elements and with the aid of the sun's energy builds up, or manufactures, of them very complex organic substances, as sugar and starch. Some of this organic matter which the plant has manufactured is used as food by the plant itself for the purpose of carrying on its own vital processes, and in thus furnishing energy for the life and work of the plant this complex matter is reduced to carbon dioxid, water, etc., and in these simple forms is thrown off by plant respiration ; but the rest of this manufactured organic matter is in part converted into the plant tissues and in part stored up in the plant either for its own subsequent use or for other purposes.

The animal, on the other hand, must depend for its energy on food alone. It has no power to manufacture its own food from elementary substances, but must have the ready-formed, complex organic matter. Some of this is transformed by the animal into its own body, but by far the larger part is burned in the body to furnish force and heat, and is then thrown off in the simple forms of carbon dioxid, water, etc. In a study of food for animals it is of chief importance to learn how much and what kinds of these organic compounds the food contains.

Foods are separated by analysis into the six different substances or groups of substances which are numbered below :

1. *Water.* In grain or hay which seems very dry there is still a considerable amount of water, or moisture, usually not less than 10 per cent. In ensilage, in green fodders, and in root crops the amount of water is very much more, usually from 70 to 90 per cent. After the water is removed from a food, all that remains is called *dry matter*.

2. *Ash.* By the term *ash* is meant the mineral matter which remains when the dry matter is burned. The ash consists of such compounds as sodium chlorid (common salt), potassium carbonate (contained in lye from wood ashes), magnesium sulfate (Epsom salts), calcium phosphate ("lime phosphate"), silicon dioxid (sand), and iron oxid.

That part of the dry matter which passes off in burning is called *organic matter*. This contains only the four elements, nitrogen, carbon, hydrogen, and oxygen; but these are united in many different complex compounds. These constitute by far the largest and most valuable part of food. This organic matter is separated by analysis into four classes :

3. *Protein.* All of the organic compounds which contain nitrogen are called *protein* (carbon, hydrogen, and oxygen are also present in protein). The gluten of wheat flour is one kind of protein.

4. *Fat.* This substance is composed of carbon and hydrogen with a small amount of oxygen. It consists mainly of the various oils and fats contained in plants, some examples of which are cotton-seed oil, linseed oil, corn oil, etc. After subtracting the protein and the fat from the organic matter the remainder is called *carbohydrates*. A *carbohydrate* is composed of carbon, hydrogen, and oxygen, the last two elements being present in the same ratio to each other as they are in water. In analysis carbohydrates are separated into two classes:

5. *Fiber.* The woody structure, or frame-work, of plants is called fiber. The fiber of flax and that of hemp are familiar examples. Paper is largely made from woody fiber.

6. *Carbohydrate extract.* This substance consists of the more easily soluble carbohydrates, sugar, starch, etc., which are separated from the fiber by extraction with acid and alkaline solutions. (These extracted carbohydrates are often called by the indefinite term *nitrogen-free extract.*)

In the following table is given the average composition of a number of American food-stuffs of importance to Illinois agriculturists. (The compilation of Jenkins and Winton and analyses by the Minnesota, North Carolina, and Illinois experiment stations have been used in making these averages.)

The composition of all the food-stuffs is given on the basis of 100 parts of dry matter in order that they may be comparable, the amount of water being so variable with changes of weather etc., that a fair comparison cannot be made on the basis of fresh substance.

The first column shows the total number of analyses of which the average is given. The second column shows the amount of food required for 100 parts of dry matter, the difference being water, as shown in the next column. The remaining columns show the percentage composition of the dry matter.

TABLE 16. AVERAGE COMPOSITION OF SOME AMERICAN FOOD-STUFFS.

Food-stuffs.	No. of complete analyses.	Composition of food-stuffs per 100 parts of dry matter.						
		Total fresh substance.	Water.	Ash.	Protein.	Fat.	Fiber.	Carbohydrate extract
*Corn-fodder (field cured)..	35	173.0	73.0	4.7	7.8	2.8	24.7	60.0
*Corn stover (field cured)..	60	166.9	66.9	5.7	6.4	1.7	33.0	53.2
Clover hay	38	118.1	18.1	7.3	14.5	3.9	29.1	45.2
Timothy hay................	68	115.2	15.2	5.1	6.8	2.9	33.5	51.7
Oat straw..................	12	110.1	10.1	5.6	4.4	2.5	40.7	46.8
Corn ensilage	102	472.0	372.0	6.6	8.1	3.8	28.5	53.0
Clover ensilage	5	357.1	257.1	9.3	14.9	4.1	29.9	41.7
Cow pea ensilage	4	360.0	260.0	10.0	14.3	2.9	27.0	45.8
Soja bean ensilage	4	405.0	305.0	13.5	13.6	4.5	32.7	35.7
Corn	86	111.9	11.9	1.7	11.5	5.6	2.6	78.6
Oats	30	112.4	12.4	3.4	13.2	5.6	10.8	67.0
Barley	10	112.2	12.2	2.7	13.9	2.0	3.0	78.4
Wheat	310	111.7	11.7	2.0	13.3	2.3	2.0	80.4
Wheat bran............. ...	88	113.5	13.5	6.6	17.4	4.5	10.2	61.3
Gluten meal................	32	110.6	10.6	.8	32.5	7.0	1.8	57.9
Cotton seed meal	35	108.9	8.9	7.8	46.1	14.2	6.1	25.8

*By corn-fodder is meant the whole plant as cut; what is left after the ears are removed is called corn stover.

THE DIGESTIBILITY OF FOODS.

When food is taken into the stomach, it is, in one sense, not yet in the system of the animal; but it is in a tube which runs through the body. This tube is called the alimentary canal. It consists of the mouth, throat, stomach, small intestines, and large intestines. When food is taken into this alimentary canal it is acted upon and partly dissolved by certain liquid agents, as the saliva in the mouth, the gastric juice in the stomach, and other liquids in the intestines. That part of the food which is dissolved is said to be digested. It passes through the walls of the alimentary canal and into the true system of the animal. It enters the circulation and may be carried to any part of the animal body. But that part of the food which cannot be dissolved by these digestive fluids is indigestible. It passes on through the alimentary canal and is excreted as dung.

It is, of course, only the digestible portion of the food that is of value for energy and the formation of animal products, and it is now readily understood that the composition alone does not determine the value of food, but rather that the value depends both upon the composition and the digestibility.

There are very important differences in the digestibility of different foods, and also of the different substances in the same food. The *per cent.* which is digestible of any substance is called the *digestion coefficient* of that substance. For example, if cattle digest 63 per cent. of the total dry matter of corn-fodder, then 63 is the *digestion coefficient* of the dry matter. Seventy-four is the *digestion coefficient* of the fat in corn-fodder because 74 per cent. of the total amount of fat is digestible.

Table 17 shows the digestion coefficients of a number of important food-stuffs.

TABLE 17. DIGESTIBILITY OF FOOD-STUFFS AS DETERMINED BY AMERICAN DIGESTION EXPERIMENTS.

	No. of single experiments.	Digestion Coefficients.						Determinations made by experiment stations of—
		Dry matter.	Ash.	Protein.	Fat.	Fiber.	Carbohydrate extract.	
With cattle—								
Corn-fodder	12	63	27	42	74	67	66	Pa., Wis., and Ill.
Corn stover	4	62	45	52	52	67	64	Pennsylvania.
Corn ensilage	17	64	32	49	82	63	68	Pa., Wis., N. C. and Ill.
Cow pea ensilage	4	60	30	58	63	52	73	Illinois.
Soja bean ensilage	4	50	28	55	49	43	61	Illinois.
With sheep—								
Timothy hay	12	59	37	49	67	56	64	Maine.
Clover hay	7	53	37	52	48	47	60	Wis. and Maine.
Wheat bran	7	61	....	78	72	25	68	Maine and Mass.
Gluten meal	2	87	....	87	88	33	91	Maine.
With swine —								
Corn meal	2	90	....	88	80	39	94	Maine and Minn.
Corn (shelled)	1	83	....	69	46	38	89	Maine.

Now, by knowing the composition of food and also the digestibility of the different substances which the food contains, we are able to determine just the amount of each substance that is digestible by the animal. This is shown in Table 18.

TABLE 18. AMOUNTS OF DIGESTIBLE SUBSTANCES, AS DETERMINED BY COMPUTATION FROM TABLES 16 AND 17.

	Required for 100 lb. of dry matter, lb.	Pounds of digestible nutrients from 100 lb. of dry matter.						*Potential energy *(calories).
		Dry matter	Ash.	Protein.	Fat.	Fiber.	Carbohydrate extract.	
With cattle—								
Corn-fodder	173.0	63	1.3	3.3	2.1	16.5	39.6	119,000
Corn stover	167.0	62	2.6	3.3	.9	22.1	34.0	114,000
Corn ensilage	472.0	64	2.2	4.0	3.1	18.0	36.0	121,000
Cow pea ensilage	360.0	60	3.0	8.3	1.8	14.0	33.4	111,000
Soja bean ensilage	405.0	50	3.8	7.5	2.2	14.1	21.8	90,000
With sheep—								
Timothy hay	115.2	59	1.9	3.3	1.9	18.8	33.1	111,000
Clover hay	118.1	53	2.7	7.5	1.9	13.7	27.1	98,000
Wheat bran	113.5	61	....	13.6	3.2	2.6	41.7	121,000
Gluten meal	110.6	87	....	28.3	6.2	.6	52.7	178,000
With swine—								
Corn meal	117.6	90	....	10.1	4.5	1.0	73.9	177,000
Corn (shelled)	111.9	83	....	7.9	2.6	1.0	70.0	158,000

* These terms are explained on page 206. It should be noted that Table 16 gives the composition of foods from a large number of averages; that Table 17 gives the average digestibility from a much smaller number of determinations; that Table 18 is derived from Tables 16 and 17, which are independent of each other; and, finally, that the close agreement in Table 18 between the total dry matter and the sum of its constituents is indicative of the general accuracy of the results.

THE USES OF FOOD.

The primary uses of food are (1) to form animal tissue, as muscle, bone, fat, etc., and (2) to supply energy, as muscular power, heat, etc.

Food may be converted into an animal product, as milk, for subsequent use. Fat is sometimes considered as a product which is simply stored by the animal for future use, but it is only in degree that fat differs in this respect from some other tissues of the body.

The using of food for these various purposes is called animal nutrition, and each substance in the food which the animal digests and uses is called a nutrient. The analysis of food shows what nutrients it contains, and the uses which the animal makes of these different nutrients is a most important consideration.

It may be stated that, although water usually constitutes more than half of the animal body, the water which is contained in food is of no more value as a nutrient than the same amount of water from the well or spring.

Ash, or mineral matter, contributes largely to the formation and repair of the skeleton. It is usually stated that most food-stuffs contain such an abundant supply of ash that this subject needs no further mention; but that the subject is worthy of careful consideration has been proved by such experiments as Professor Henry reports from the Wisconsin Experiment Station in Bulletin No. 25. The experiments were made with a large number of pigs, which were divided into three groups. The pigs of the first group were fed corn meal; those of the second group, corn meal and hard-wood ashes, and those of the third group were fed corn meal and bone meal. From the average results of three separate trials, Professor Henry draws the conclusion that the effect of the bone meal and ashes was to save about 130 lb. of corn in producing 100 lb. of gain in the live weight of the hogs; and he recommends that either hard-wood ashes or bone meal be fed with corn.

Protein is the only nutrient of the food which contains the element nitrogen. Something of the importance of protein in the food may be understood from the fact that the flesh, or lean meat, the hide, membranes, ligaments, tendons, internal organs, and, in fact, all working parts of the body, excepting the bones, are composed almost entirely of protein; and they cannot be formed from anything but protein. The casein of milk is protein; and the albumen, or white, of eggs is a very pure form of protein.

For the highest production of milk or eggs or animal growth, foods rich in protein are necessary. Protein is also used to furnish energy, and it may be used for the production of animal fat; but protein is so expensive that there is usually no profit in feeding it for those uses.

Fat of the food may be used to supply energy, or it may be transformed into animal fat.

Carbohydrates, both the fiber and the more soluble carbohydrate extract, are used mainly to furnish energy, but they are also converted to a considerable extent into animal fat.

It should be borne in mind that fat and carbohydrates serve the same purposes in animal nutrition, viz.—the production of force, heat, and animal fat; while protein serves primarily a very different purpose—the building and repairing of nearly all of the working parts of the animal body.

In calculating the values of foods the water and ash are usually omitted, but the amount of digestible protein is carefully considered, and also the total value of the digestible food as a source of energy. This power of food to furnish energy when burned in the body is called its *potential energy* (sometimes called "fuel value"), and it is measured in "heat units," which are called *calories*. A *calorie* is the amount of heat required to raise the temperature of one kilo (about 2.2 lb.) of water one degree centigrade (1.8 degrees F.). The potential energy of one pound of carbohydrates or of protein has been found to be 1,860 calories, and of one pound of fat 4,220 calories.

The potential energy of foods is given in the last column of Table 18.

Feeding Standards.

One of the important things to keep in mind in making up rations for stock feeding is the fact that protein serves a special purpose, that nothing else can take its place, and that it is usually the most expensive constituent of the food. If the animal is required to furnish nitrogenous products, as milk, eggs, or animal growth, of course much more protein is required than by an animal which is not producing such substances; but even in the latter case experiments have shown that some protein is necessary for the repair of the tissues of the body which are broken down in work or worn out with use. Thus protein is continually required by the animal.

Another important fact is, that the animal must have food for its energy—food which is burned in the body to furnish heat for keeping the body warm, and muscular power for internal and external work.

TABLE 19. (*From Wolff's Feeding Standards.*) Daily Requirements for 1,000 Pounds live Weight of Animals.

	Protein, pounds.	Potential energy, calories.
Milk cows	2.5	30,000
Horses:		
At moderate work	1.8	27,000
At heavy work	2.8	34,000
Oxen:		
At rest in stall	0.7	17,000
At moderate work	1.6	25,000
At heavy work	2.4	31,000
Fattening oxen:		
First period	2.5	35,000
Second period	3.0	36,000
Third period	2.7	35,000
Growing cattle:		
Of 150 lb. average live weight	4.0	42,000
Of 300 " " " "	3.3	36,000
Of 500 " " " "	2.6	33,000
Of 700 " " " "	2.0	30,000
Of 850 " " " "	1.6	27,000
Wool sheep:		
Coarser breeds	1.2	22,000
Finer breeds	1.5	25,000
Fattening sheep:		
First period	3.0	36,000
Second period	3.5	36,000
Growing sheep:		
Of 56 lb. average live weight	3.2	38,000
Of 67 " " " "	2.5	31,000
Of 75 " " " "	2.1	27,000
Of 85 " " " "	1.4	23,000
Fattening swine:		
First period	5.0	60,000
Second period	4.0	52,000
Third period	2.7	38,000
Growing fat swine:		
Of 50 lb. average live weight	7.6	70,000
Of 100 " " " "	5.0	56,000
Of 170 " " " "	3.4	44,000
Of 250 " " " "	2.5	35,000

The value of digestible food is represented by the protein and the potential energy. In regard to the amounts of food an animal will require for its protein and potential energy, much will depend upon what is required of the animal. The food required by an animal which is at rest and is neither growing nor fattening will not supply the needs of a growing, fattening, or working animal, or of one that is required to produce milk or eggs. Many carefully conducted experiments have been made to determine the amounts and kinds of food required by the various farm animals when kept for different purposes. From the results of these experiments there have been worked out *feeding standards*, that is, standard directions for feeding. The feeding standards of Dr. Emil Wolff are widely used. These are given in Table 19.

According to Wolff's standard, a milk cow of 1,000 pounds weight requires a daily ration which represents 2.5 pounds of digestible protein and 30,000 calories of potential energy, although it may be that under certain conditions it is not the most profitable ration for the dairy farmer. Of course, the value or cost of food and the selling price of the animal product must not be overlooked, but it can in no way alter the truth that the cow will do her best on an ideal, or well balanced, ration; and certainly such a ration should be fed if it can be done at no extra cost.

By referring to a table which gives the pounds of protein and the calories of energy furnished by different foods (see Table 18) it is a simple matter to make up a desired ration. For example, 70 lb. of cow pea ensilage and 7.5 lb. of wheat bran will furnish 2.5 lb. of protein and 30,000 calories of energy, Wolff's standard ration for milk cows per 1000 pounds live weight.

Of course, these food-stuffs could be replaced in part or entirely by equivalent amounts of clover hay or corn-fodder and corn meal, gluten meal or any other suitable food materials, provided that the full ration does not exceed the total amount of food which the animal will eat.

It should be noted that this bulletin does not discuss the subject of animals, but it deals only with the question of foods.

One animal may eat much more food than another, even though they are of equal weight, and are offered the same kinds of food. This difference is due, of course, to the individuality of the animal. The one is said to be a "good feeder," the other a "poor feeder." Or, two cows may eat *and digest* equal amounts of the same kinds of food, and yet one cow may produce much more butter fat than the other. This, again, is due to the animal and not to the food. Especially do animals bred for different purposes show marked differences in their ability to make milk or meat from equal amounts of digested food. Much study has been given by stock breeders to these animal characteristics, and they are important considerations; but they do not lessen the importance of providing sufficient and well balanced rations. As stated before, feeding standards are derived from the results of many carefully conducted experiments, but they are not to be regarded as infallible conclusions strictly applicable to every condition of stock raising. They are intended not to replace but to supplement the intelligence of the stock feeder.

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