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3-1-1925

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Dunbar, B.A., "Effects of Feeding Extremely Wide Rations to Horses" (1925). *Bulletins.* Paper 212.
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Bulletin 212 March, 1925

Effects of Feeding Extremely Wide Rations To Horses

Chemistry Department
Agricultural Experiment Station
of the
South Dakota State College of
Agriculture and Mechanic Arts
Brookings

FOREWORD

In publishing this bulletin, the author wishes to give credit to Professor James H. Shepard, former Chemist of this Station, who started this investigation but whose untimely death occurred before the experiment was completed. Valuable assistance in the chemical work was also rendered by Mr. Gay Youngberg, Mr. R. G. Sherwood, and Mr. C. W. Middleton.

Credit is also acknowledged to the Veterinary Department for their valuable cooperation in carrying on this experiment; to Dr. E. L. Moore, deceased, for aid during the earlier period of the experiment and to Dr. C. C. Lipp for more recent assistance.

EFFECTS OF FEEDING EXTREMELY WIDE RATIONS TO HORSES

B. A. Dunbar, Chemist

A common practice of many of our farmers of the Northwest has been to turn out their young or idle stock to gain a living from otherwise waste forage around the farm, particularly to strawstacks, with no other feeding of a systematic character during the months of idleness. It was an accepted matter of knowledge that stock so treated developed a more or less emaciated, potbellied, and rough-coated appearance and had every symptom of under-nourishment. With these observations in mind an investigation was undertaken, with the cooperation of our veterinary department. This study undertook to determine the effects, anatomic and metabolic, which might follow the feeding to normal and healthy horses, of oat straw alone, as a type of an unbalanced and extremely wide ration.

With this in view, three horses were selected for the experiment. These animals were, to all appearances and by veterinary standards, healthy, normal and average work horses of the ordinary farm types, without blemish and typical of the farm animal usually found in daily use. The animals are designated as Horse No. 1, Horse No. 2, and Horse No. 3. No. 1 was approximately twelve years of age at the beginning of the experiment, weighing 1,208 pounds at that time. No. 2 was a grade Hambletonian, eleven years old, weighing 1,180 pounds. No. 3 was a grade English Shire, seven years of age, weighing 1,518 pounds. These were the same horses that had been used in a previous experiment and hence were thoroughly accustomed to the sacks and stalls which were to be employed during this part of the work. The general appearance of the animals is shown in Figures I, II and III, made from photographs taken at the beginning of this experiment.

The feed used in the experiment consisted of oat-straw only. In 1912, three lots of straw were used. These lots are designated as Straw-M, Straw-E and Straw-W, respectively. During the following years of the experiment, but one lot of straw was used for each full season's feeding. Composite samples of these feeds were taken from various points in the lots for all analyses.

The general method followed during these experiments is described in the following pages with several modifications during the years 1913-1916 due to increasing knowledge of the necessities of the problem.

The actual feeding experiment was carried on during each of the years in periods of from ninety to one-hundred-twenty days each, depending upon the convenience of the operators and the ability to prolong the experiment. The time consumed was partially dependent upon the character of the season as to early or late spring planting.

The feeding was begun as early in the year as circumstances would permit, usually near the latter part of January or the first of February. After the feeding season was complete, the animals were allowed to run idle and to feed as other horses of the Station Farm, but they were not used as work horses at any time during the years of this experiment. This gave them an opportunity to recuperate as much as possible from the effect of the previous feeding season before the beginning of the next.

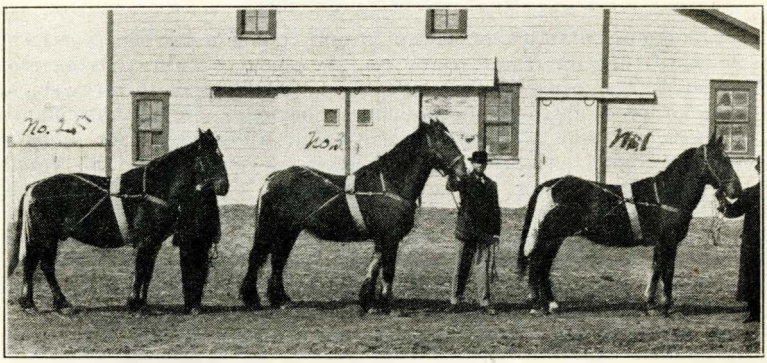

Fig. 1.—Side view of horses used in the experiment, at its beginning. From left to right—No. 2, No. 3, No. 1.

Each of these annual experimental seasons was subdivided into the following periods: a preliminary ten-day period of preparation to allow the animals to become accustomed to the feed and sacks. During this period, oat straw only was fed. Then followed a five-day period during which digestion coefficients were determined, using oat straw. At the end of this period, the sacks were removed and the feeding continued as before, but at the end of every ten-day period after the close of the period of digestion-coefficient determination, feces were collected during a twenty-four hour period. All of the material voided was collected as the feces to be analyzed for that interval. At this interval, the waste straw was also collected, mixed with such samples collected at the other ten-day intervals, and a composite aliquot analyzed as waste straw for the season's run. During the season of 1912, and at the end of the feeding season, a second period of five days was devoted to the determination of digestion coefficients. However, it was not found necessary to run this second determination during succeeding years, the determination of digestion coefficients being made at the first of the feeding season only, during the years 1913-1916.

During the season of 1912, as previously mentioned, three lots of straw were fed, and in the following rotation: during the first digestion coefficient period of five days, as well as in preliminary feeding, Straw-E was used; during the second or final period of five days, Straw-M was fed; in the intervening time between the two digestion coefficient determinations, a mixture of straws E-M-W was used.

Throughout the entire time of experimentation in each year, the animals were given all the straw they would eat; they were well cared for in clean surroundings, and were at all times plentifully supplied with water, and had access to salt.

From time to time, anatomical measurements were made under the supervision of the Station Veterinarian. The animals were weighed at approximately ten-day intervals throughout the actual experimentation season. At convenient times, blood counts were

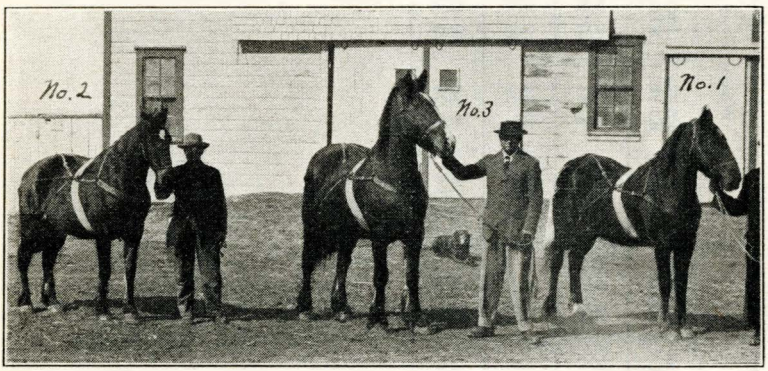

Fig. 2.—Front view of horses at beginning of experiment. From left to right—No. 2, No. 3, No. 1.

taken during the first four years of the work. During two of these years, counts of both red and white corpuscles were recorded.

The results obtained during the feeding season of 1912, from January 25 to April 23 inclusive, are recorded in the following pages.

SEASON OF 1912

The three lots of straw fed during this year's experimentation were analyzed, with the results recorded in Table I.

TABLE I—ANALYSIS OF OAT STRAW FED—1912

Constants	Straw-E		Straw-M		Straw-W		Mixture	
	Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free
Moisture	9.03%	.....	8.02%	.....	7.08%	.....	8.04%	.....
Ash	6.64	7.30%	7.61	8.27%	6.21	6.68%	6.82	7.42%
Ether Extract.	2.35	2.58	3.71	4.03	2.33	2.51	2.80	3.04
Crude Fiber...	39.91	43.87	37.14	40.38	41.61	44.88	39.55	43.04
Crude Protein.	6.06	6.66	4.18	4.55	3.25	3.40	4.50	4.87
N-Free Extr...	36.01	39.59	39.34	42.77	39.52	42.53	38.29	41.63

In computing digestion coefficients during the two five-day periods previously mentioned, the percentage results of Table I were used in the calculation of the dry constants of the material fed. The percentages obtained by the analysis of the wastage collected at the

TABLE II—COMPOSITE ANALYSIS OF WASTE STRAW—FIVE DAY PERIODS—1912

Horse and Period		Air-Dry Material						Water-Free Material				
		Water	Ash	Ether Extr.	Crude Fiber	Crude Prot.	N-Free Extr.	Ash	Ether Extr.	Crude Fiber	Crude Prot.	N-Free Extr.
Horse No. 1	Jan.	10.77%	5.70%	2.41%	38.37%	5.00%	37.75%	6.39%	2.70%	43.00%	5.60%	42.31%
	Apr.	6.21	5.78	2.20	43.13	3.44	39.24	6.16	2.35	45.99	3.66	41.84
Horse No. 2	Jan.	10.06	5.73	2.48	38.17	5.78	37.78	6.38	2.76	42.44	6.53	41.89
	Apr.	6.15	5.75	2.12	43.58	3.13	39.27	6.13	2.26	46.44	3.33	41.84
Horse No. 3	Jan.	9.71	6.05	2.42	38.25	5.46	38.11	6.70	2.68	42.31	6.05	42.26
	Apr.	5.60	5.75	2.37	42.89	3.44	39.95	6.10	2.51	45.43	3.64	42.32

end of each of these five-day periods were employed in the calculation of dry constants not eaten. The difference between these two results—dry material fed and dry material not eaten—was regarded as dry matter actually eaten. Table II contains percentages of constants present in the waste straw collected at the end of the five-day periods referred to.

Basing calculations upon the data of Tables I and II, and upon the dry matter eaten and voided as calculated, digestion coefficients were determined for the two five-day periods, which are given in Table III.

TABLE III—DIGESTION COEFFICIENTS—TWO PERIODS OF 1912.

Period	Horse	Item	Grams Ash	Grams Ether Extract	Grams Crude Fiber	Grams Crude Prot.	Grams N-Free Extract	Grams Dry Matter Eaten
Jan.	No. 1	Eaten	1986	625	11122.	1853	9414	25000
		Voided	1026	554	4297	780	5762	12419
		D. Coef.	48.33	11.38	61.37	57.92	38.79	50.33
	No. 2	Eaten	2902	1008	17277	2624	15437	3?4 8
		Voided	1570	879	1744	1322	9011	20526
		D. Coef.	45.89	12.85	55.18	49.63	41.63	47.70
	No. 3	Eaten	2667	921	15874	2439	14028	35929
		Voided	1566	833	7628	1158	9532	20717
		D. Coef.	41.27	9.57	51.95	52.93	32.05	42.34
	Ave.	D. Coef.	46.16	11.27	56.17	53.49	37.49	46.79
April	No. 1	Eaten	3153	1610	13638	1701	15202	35304
		Voided	1862	1086	6600	1045	7936	18529
		D. Coef.	40.95	32.55	51.61	38.58	47.78	47.59
	No. 2	Eaten	3517	1752	16415	1933	17659	41276
		Voided	2372	1420	9658	1479	10744	25673
		D. Coef.	32.55	18.90	41.16	23.49	39.16	37.81
	No. 3	Eaten	3415	1697	15601	1855	16921	39489
		Voided	2195	1293	8337	1377	10103	
		D. Coef.	38.64	23.77	46.57	25.75	40.10	40.98
	Ave.	D. Coef.	37.38	25.07	46.45	29.27	42.35	42.13

The items of Table III, designated as "Grams Dry Matter Eaten" and "Grams Dry Matter Voided," were not only arrived at by the summation of the calculated constants, but were checked to accuracy by actual drying tests upon feces collected during each five-day digestion trial.

The analysis of composite samples of the feces, collected during the two trials, is indicated in Table IV.

Attention is called to the sharply defined differences that occur in the average ability to retain and to make use of the above feeding constants at the first of the season and at the close. Particularly

TABLE IV—ANALYSIS OF FECES—DIGESTION TRIALS OF 1912

Horse and Period		Air-Dry Basis						Water-Free Basis				
		Water	Ash	Ether Extr.	Crude Fiber	Crude Prot.	N-Free Extr.	Ash	Ether Extr.	Crude Fiber	Crude Prot.	N-Free Extr.
Horse No. 1	Jan.	2.54%	8.05%	4.35%	33.72%	6.12%	45.22%	8.26%	4.46%	34.60%	6.28%	46.40%
	Apr.	5.80	9.47	5.52	33.55	5.31	40.35	10.05	5.86	35.62	5.64	42.83
Horse No. 2	Jan.	3.02	7.42	4.15	36.59	6.25	42.57	7.65	4.28	37.73	6.44	43.90
	Apr.	7.88	8.51	5.09	34.66	5.31	38.55	9.24	5.53	37.62	5.76	41.85
Horse No. 3	Jan.	2.77	7.35	3.91	35.80	5.44	44.73	7.56	4.02	36.82	5.59	46.01
	Apr.	7.37	8.73	5.14	33.13	5.47	40.16	9.42	5.55	35.77	5.91	43.35
Average	Jan.	2.78	7.61	4.14	35.37	5.94	44.17	7.82	4.25	36.38	6.10	45.44
	Apr.	7.02	8.90	5.25	33.78	5.36	39.69	9.57	5.65	36.34	5.77	42.68

TABLE V—ANALYSIS OF FECES—10 DAY COMPONENTS—1912

Horse No.	CONSTANT	10 Days		20 Days		30 Days		40 Days	
		Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free
1	Water	77.06	.....	75.89	.....	76.47	.....	74.12	.....
	Ash	2.03	8.85	1.78	7.38	2.16	9.18	2.72	10.51
	Ether Extract	1.04	4.53	1.01	4.19	1.21	5.14	1.31	5.06
	Crude Fiber	9.41	41.02	9.19	38.12	8.68	36.89	8.84	34.16
	Crude Protein	1.60	6.98	1.44	5.98	1.41	5.99	1.56	6.03
	N-Free Extract	8.86	38.62	10.69	44.33	10.07	42.80	11.45	44.24
2	Water	76.49	.....	77.28	.....	75.20	.....	75.40	.....
	Ash	1.69	7.19	1.81	7.97	2.47	9.96	2.25	9.55
	Ether Extract	1.03	4.38	0.98	4.31	1.35	5.44	1.13	4.59
	Crude Fiber	9.11	38.75	8.74	38.47	8.84	35.65	8.81	35.82
	Crude Protein	1.51	6.42	1.32	5.81	1.57	6.33	1.45	5.89
	N-Free Extract	10.17	43.26	9.87	43.44	10.57	42.62	10.86	44.15
3	Water	78.40	.....	79.24	.....	76.80	.....	77.10	.....
	Ash	1.65	7.64	1.64	8.14	2.49	10.73	2.42	10.57
	Ether Extract	0.95	4.40	0.87	4.19	1.15	4.96	1.10	4.80
	Crude Fiber	8.05	37.27	8.04	38.73	7.94	34.22	7.97	34.80
	Crude Protein	1.35	6.25	1.34	6.45	1.51	6.51	1.50	6.55
	N-Free Extract	9.60	44.44	8.82	42.49	10.11	43.58	9.91	43.28
Ave.	Water	77.32	.....	77.47	.....	76.16	.....	75.54	.....
	Ash	1.79	7.89	1.76	7.83	2.37	9.96	2.50	10.21
	Ether Extract	1.01	4.44	0.95	4.23	1.24	5.18	1.18	4.82
	Crude Fiber	8.86	39.01	8.66	38.44	8.49	35.59	8.54	34.93
	Crude Protein	1.49	6.55	1.37	6.08	1.50	6.28	1.50	6.16
	N-Free Extract	9.54	42.11	9.79	43.42	10.25	43.00	10.74	43.89

TABLE V—Concluded

Horse No.	CONSTANT	50 Days		60 Days		70 Days		80 Days	
		Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free
1	Water	76.39	.....	78.90	.....	78.07	.....	77.12	.....
	Ash	2.43	10.29	2.00	9.48	2.09	9.53	2.46	11.15
	Ether Extract	1.24	5.25	1.07	5.07	1.16	5.29	1.22	5.24
	Crude Fiber	8.29	35.11	7.65	36.26	7.87	35.89	8.08	34.99
	Crude Protein	1.52	6.44	1.08	5.11	1.42	6.48	1.51	6.60
	N-Free Extract	10.13	42.91	9.30	44.08	9.39	42.81	9.61	42.00
2	Water	77.46	.....	76.60	.....	78.12	.....	78.35	.....
	Ash	2.22	9.85	2.09	8.94	2.30	10.51	2.10	9.70
	Ether Extract	1.13	5.01	1.10	4.70	1.27	5.80	1.13	5.22
	Crude Fiber	8.00	35.49	8.86	37.86	7.83	35.79	7.90	36.49
	Crude Protein	1.37	6.08	1.36	5.81	1.21	5.53	1.54	7.11
	N-Free Extract	9.82	43.57	9.99	42.69	9.27	42.37	8.98	41.48
3	Water	78.63	.....	78.99	.....	78.92	.....	79.75	.....
	Ash	2.18	10.21	2.00	9.52	2.22	10.53	2.05	10.12
	Ether Extract	1.05	4.91	1.01	4.81	1.21	5.74	1.02	5.04
	Crude Fiber	7.70	36.03	7.78	37.03	7.41	35.15	7.37	36.39
	Crude Protein	1.35	6.32	1.18	5.61	1.36	6.45	1.44	7.11
	N-Free Extract	9.09	42.53	9.04	43.03	8.88	42.13	8.37	41.34
Ave.	Water	77.49	.....	78.16	.....	78.37	.....	78.41	.....
	Ash	2.28	10.12	2.03	9.31	2.20	10.19	2.20	10.32
	Ether Extract	1.14	5.06	1.06	4.86	1.21	5.61	1.12	5.17
	Crude Fiber	8.00	35.54	8.10	37.05	7.70	35.61	7.78	35.96
	Crude Protein	1.41	6.28	1.21	5.51	1.33	6.15	1.50	6.94
	N-Free Extract	9.68	43.00	9.47	43.27	9.18	42.44	8.99	41.61

striking is this difference in the items of mineral and fats on the one hand, and of fiber, protein and starchy materials on the other. This difference will be mentioned again in the general summary at the close of the bulletin.

Table V indicates the results of analyses of composite samples of feces, collected at ten-day intervals, between the periods allotted to determination of digestion coefficients. All these analyses were conducted upon the air-dry material; then calculated to water-free basis.

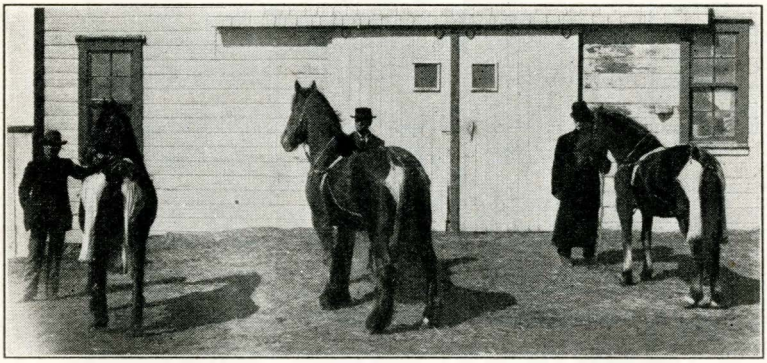

Fig. 3.—Rear view of horses at beginning of experiment. From left to right—No.2, No. 3, No. 1.

From time to time during this year's work, blood counts were taken and anatomical measurements were made. Table VI gives these data for the season under immediate discussion.

Interesting conclusions might be drawn from the data covering the work of 1912, but they are left to the summary at the conclusion of this report.

The work as carried on during the succeeding years of the experiment is reported in a more generalized manner, as far as tabulation is concerned. The slight modifications made in method are mentioned as the tables are introduced. The work of 1913-1916 was modified by the fact that Horse No. 1 was eliminated from the experiment at or near the close of the feeding season of 1913 by death. The report given by the veterinarian, covering his observations from an autopsy upon the body of Horse No. 1, says:

"Throughout the feeding period of 1912, Horse No. 1 steadily failed in general health and showed evidences of physical breakdown. Horses No. 2 and No. 3 held their own fairly well, but No. 1 became emaciated, although eating and drinking quite regularly. Early in the spring of 1913, No. 1 became lame. At first, the seat of trouble was thought to be located in the left stifle. The horse continued to be lame and this lameness seemed to increase so that he could not be led or even moved out of his stall. About this time, it was noted that the left femoiliac articulations had been dislocated. The animal was continually getting cast in his stall and had to be

TABLE VI—MEASUREMENTS AND BLOOD COUNTS—1912

Horse No.	Date	Bl. Ct. Eryth-roc. Thou-sands	Bl. Ct. Leucoc.	Weight lbs.	Girth ft. in.	Triceps to Triceps	Point-Shoul-der to Oppo-site	With-ers to Left Pecto-rals	With-ers to Right Pecto-rals	Hip to Hip	Trans-Diam. Left Thigh	Ant.-Post. Left Thigh	Trans-Diam. Right Thigh	Ant.-Post. Right Thigh
1	Jan. 30.....	9298	1555.5	1208	7'3¾"	49.0"	37.0"	78.6"	77.0"	52.0"	27.6"	29.5"	27.0"	27.2"
	Feb. 14.....				7'2½"	48.0"	38.2"	76.6"	79.0"	50.8"	26.1"	27.1"	27.6"	30.1"
	Feb. 27.....			1190	7'1½"	49.1"	38.8"	77.1"	77.8"	51.7"	27.0"	28.5"	27.1"	28.5"
	Mar. 8	7960	2222.2	1166	6'11½"	45.5"	37.2"	76.2"	77.5"	51.0"	26.0"	28.8"	27.0"	29.7"
	Mar. 21.			1154	7'0"	47.3"	37.5"	76.3"	75.0"	55.0"	26.1"	26.9"	27.6"	29.0"
	Mar. 28.....			1152	7'0"	47.5"	37.0"	78.0"	78.3"	51.1"	26.0"	31.2"	26.5"	35.7"
	Apr. 8	6052	4444.4	1132	6'10"	44.7"	37.0"	76.4"	78.1"	50.2"	26.6"	27.6"	25.7"	29.1"
	Apr. 15.....			1127	6'10"	47.1"	36.8"	76.5"	77.5"	50.3"	26.3"	29.7"	26.0"	30.0"
	Apr. 23.....			1115	6'8¾"	47.3"	37.1"	75.6"	74.8"	50.0"	24.5"	29.7"	27.5"	29.0"
2	Jan. 30.....	7840	1555.5	1180	7'½"	45.0"	38.3"	72.7"	73.2"	54.2"	24.0"	33.0"	25.3"	31.0"
	Feb. 14.....				6'11"	47.1"	37.5"	72.3"	72.9"	53.8"	23.2"	26.4"	31.1"	32.5"
	Feb. 27.....			1174	6'10"	46.0"	38.0"	73.2"	73.2"	53.4"	23.8"	30.5"	25.3"	31.2"
	Mar. 8	7240		1150	6'9"	45.5"	37.2"	73.3"	72.6"	53.4"	24.0"	31.0"	24.1"	33.1"
	Mar. 21.....			1128	6'8"	44.0"	36.0"	71.7"	72.7"	52.6"	22.6"	32.5"	26.0"	34.0"
	Mar. 28.....			1140	6'8"	48.9"	38.2"	72.2"	71.6"	52.8"	24.4"	31.5"	26.5"	33.3"
	Apr. 8			1124	6'7½"	45.5"	37.0"	71.5"	71.6"	53.3"	24.1"	30.8"	24.7"	32.7"
	Apr. 15.....			1127	6'8"	43.7"	36.0"	72.0"	72.7"	51.5"	23.2"	30.7"	26.7"	32.0"
	Apr. 23.....	7136	2000.0	1125	6'6¾"	45.1"	36.1"	71.6"	71.6"	52.0"	22.8"	31.6"	25.6"	33.5"
3	Jan. 30.....	7792	883.8	1518	7'7¼"	46.5"	43.0"	81.6"	81.0"	60.5"	29.5"	33.4"	28.1"	33.3"
	Feb. 14.....				7'7½"	52.0"	43.2"	82.2"	82.5"	60.6"	29.3"	32.2"	29.3"	33.5"
	Feb. 27.....	8860	1111.1	1500	7'5¼"	48.5"	42.5"	81.7"	81.5"	59.4"	27.5"	32.0"	26.1"	33.0"
	Mar. 8			1472	7'4½"	48.3"	41.5"	81.6"	80.9"	59.3"	27.2"	31.3"	27.9"	33.5"
	Mar. 21.....			1476	7'2¼"	47.0"	41.2"	81.0"	82.0"	60.5"	26.7"	33.2"	28.0"	33.4"
	Mar. 28.....			1464	7'5¼"	50.3"	42.2"	80.6"	81.7"	59.3"	28.0"	30.5"	27.6"	35.8"
	Apr. 8			1456	7'3"	45.7"	41.3"	81.2"	81.3"	59.8"	27.1"	34.1"	25.9"	31.7"
	Apr. 15.....			1445	7'3"	46.5"	39.5"	79.2"	80.5"	58.6"	27.1"	34.0"	25.6"	32.0"
	Apr. 23.....	5720	2666.6	1415	7'1½"	45.7"	39.6"	81.6"	81.7"	57.4"	27.7"	33.0"	26.5"	34.0"

helped to his feet every morning. He was finally destroyed and a careful autopsy made.

"At first, the skin was removed and the fore legs, including the scapulas, dissected away. The muscles were carefully removed from the bones so as not to injure the articulations in the least. The articular cartilages of the glenoid cavities of both scapuli and the corresponding surfaces of both humeri showed marked ulceration. The other articulations of the fore legs did not show any pathological changes. Next, the body was eviscerated, the hind quarters removed, and the bones carefully dissected out. The ribs and vertebral column were relieved of their muscles. No broken ribs were observed, nor were any of the processes of the vertebrae deranged in any manner. The muscles about the left hip joint were 'black and blue.' When the muscles were dissected away, the joint was shown to be dislocated. The articular cartilage was completely destroyed with the exception of a small ring about the periphery. A new articular surface had

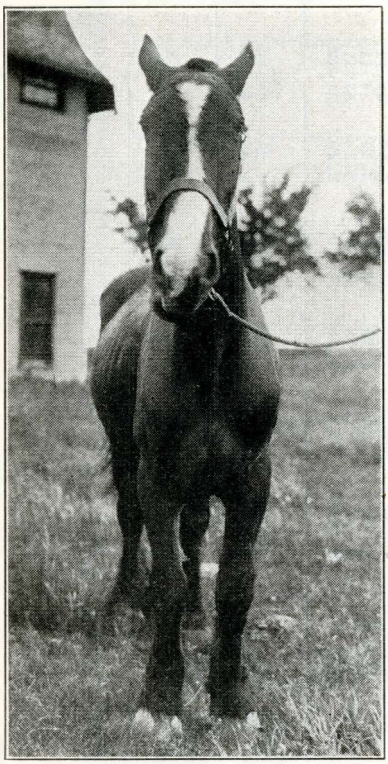

Fig. 4.—Horse No. 3 at the end of the experiment. Note the pot-bellied condition and evidence of enlarged joints.

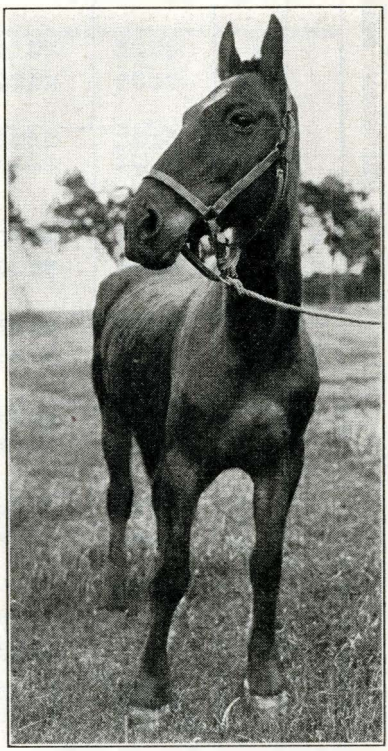

Fig. 5.—Horse No. 2 at the end of the experiment. Note the general poor condition of the animal.

TABLE VII—ANALYSIS OF OAT STRAW AS FED, OF COMPOSITE TEN-DAY COLLECTIONS OF WASTE STRAW, AND OF WASTE STRAW DURING DIG. COEF. PERIODS—1913-1916

Material & Year	Horse	Air-Dry Basis						Water-Free Basis				
		Water	Ash	Ether Extr.	Crude Fiber	Crude Prot.	N-Free Extr.	Ash	Ether Extr.	Crude Fiber	Crude Prot.	N-Free Extr.
Straw as Fed												
1913		4.95	7.53	2.08	44.34	3.50	37.60	7.92	2.19	46.65	3.68	39.56
1914		5.21	6.88	1.99	39.58	3.94	42.40	7.26	2.10	41.75	4.16	44.73
1915		4.28	5.42	1.86	41.70	4.63	42.11	5.66	1.95	43.51	4.83	43.99
1916		29.13	5.42	1.33	30.48	3.54	30.10	7.64	1.87	43.01	5.00	42.48
Waste Straw												
1913	No. 1	7.80	7.18	1.89	42.23	3.12	37.78	7.79	2.05	45.80	3.38	40.98
	No. 2	7.02	6.85	1.55	43.33	3.19	38.06	7.37	1.67	46.60	3.43	40.93
	No. 3	7.38	6.84	1.67	42.04	2.88	39.19	7.38	1.80	45.39	3.11	42.32
1914	No. 2	6.37	6.28	1.50	40.11	2.87	42.87	6.78	1.60	42.84	3.07	45.71
	No. 3	6.44	6.40	1.46	40.16	3.12	42.42	6.84	1.56	42.93	3.33	45.34
1915	No. 2	7.62	6.12	1.44	42.85	3.56	38.41	6.62	1.56	46.38	3.85	41.59
	No. 3	7.62	6.30	1.46	43.01	3.50	38.11	6.82	1.58	46.56	3.79	41.25
1916	No. 2	17.89	5.78	0.78	39.64	3.34	32.57	7.04	0.95	48.28	4.07	39.66
	No. 3	18.82	6.00	0.76	39.70	3.30	31.42	7.39	0.94	48.90	4.07	38.70
*Waste Straw During Digestion Expts. 1915	No. 2	5.60	5.51	1.70	43.18	4.25	39.76	5.84	1.80	45.74	4.50	42.12
	No. 3	4.10	5.31	1.61	44.50	4.03	40.45	5.54	1.68	46.40	4.20	42.18
*Waste Straw During Digestion Expts. 1916	No. 2	32.45	4.37	0.95	30.98	3.27	27.58	7.06	1.40	45.87	4.84	40.83
	No. 3	27.90	5.85	1.20	33.57	3.42	28.06	8.11	1.66	46.57	4.74	38.92

*This waste straw was used in 1915-1916 in determining Digestion Coefficients, instead of the composite analysis, as used in 1913-1914, and instead of the average analysis as used in 1912.

been formed below the head of the femur, in the neck. In the dislocation, the head of the femur had been thrown forward and upward so that the neck of the femur rested against the side of the innominate anterior to the glenoid cavity. Here new articular surfaces had been formed on each of the bones. The edges of the glenoid cavity were somewhat flattened and an exastosis was plainly visible.

TABLE VIII—DIGESTION COEFFICIENTS—OAT STRAW ONLY—1913-1

Year	Horse	Item	Grams Ash	Grams Ether Extract	Grams Crude Fiber	Grams Crude Prot.	Grams N-Free Extract	Total Dry Matter
1913	No. 1	Eaten	1682	483	9981	825	8025	20933
		Voided	1298	482	4056	644	4398	10878
		Dig. Coef	22.73	0.21	59.10	22.05	45.20	48.03
	No. 2	Eaten	1993	627	11892	972	9895	25379
		Voided	1439	518	4523	694	5068	12242
		Dig. Coef	27.80	17.39	61.97	28.60	48.78	51.77
	No. 3	Eaten	2225	642	12878	1071	10476	27292
		Voided	1753	635	5870	809	6405	15472
		Dig. Coef	21.21	1.09	54.42	24.46	38.86	43.31
	Ave.	Dig. Coef	23.91	6.23	58.50	25.04	44.28	47.70
1914	No. 2	Eaten	2221	686	12224	1372	13109	29612
		Voided	1623	637	6685	863	7985	17793
		Dig. Coef	26.92	7.14	45.31	37.10	39.09	39.91
	No. 3	Eaten	2635	822	14739	1577	15885	35658
		Voided	2437	968	9882	1286	12007	26581
		Dig. Coef	7.51	.....	32.95	18.45	24.41	25.46
	Ave.	Dig. Coef	17.22	.....	39.13	27.78	31.75	32.69
1915	No. 2	Eaten	1936	649	13970	1613	14547	32715
		Voided	1273	607	5545	1062	7110	15597
		Dig. Coef	34.25	6.47	60.31	34.16	51.12	52.32
	No. 3	Eaten	2438	857	18409	2132	18922	42758
		Voided	1892	1002	7941	1635	10653	23123
		Dig. Coef	22.40	.....	56.85	23.31	43.70	45.92
	Ave.	Dig. Coef	28.33	.....	58.58	28.74	47.41	49.12
1916	No. 2	Eaten	2625	659	14483	1705	14504	33976
		Voided	2079	652	9576	1189	9630	23126
		Dig. Coef	20.80	1.06	33.88	30.26	33.60	31.93
	No. 3	Eaten	3192	794	17819	2102	17914	41821
		Voided	2320	684	9711	1362	9992	24069
		Dig. Coef	27.32	13.85	45.50	35.20	44.22	42.45
	Ave.	Dig. Coef	24.06	7.46	39.69	32.73	38.91	37.19

The right hip was then dissected away, and the articulation appeared normal in every respect. The distal ends of the femurs showed ulceration about the surface of the condyles. The surface of the patellas were ulcerated. The fossa of the astraglus showed a deep ulcer, confined to its own area; that is, the articular cartilage, up to the ulcer-pit, appeared to be normal. From this we were able to conclude that both hocks were spavined. Below the hocks in both hind legs, the articulations appeared to be normal in every respect."

By reason of the necessity of destroying Horse No. 1 at the close of the season of 1913, data for 1914, 1915, and 1916 are derived from experimentation upon horses No. 2 and No. 3 only.

WORK OF 1913-1916

From 1913 to 1916, the work was somewhat simplified by the use of but a single lot of oat straw in the feeding, and by the further fact that it was recognized as unnecessary to run more than one digestion coefficient trial per year. The feeding season was continued after this first five-day trial for as many ten-day intervals as the character of the season seemed to warrant. The work was also lessened by the conducting of but one analysis of the waste straw as a composite of the several ten-day collections of the refuse. This was regarded as ample for purposes of accuracy. The results of these four years of work are tabulated in the following pages. All tables are condensed as far as possible without loss of comparative data for reference with results of 1912.

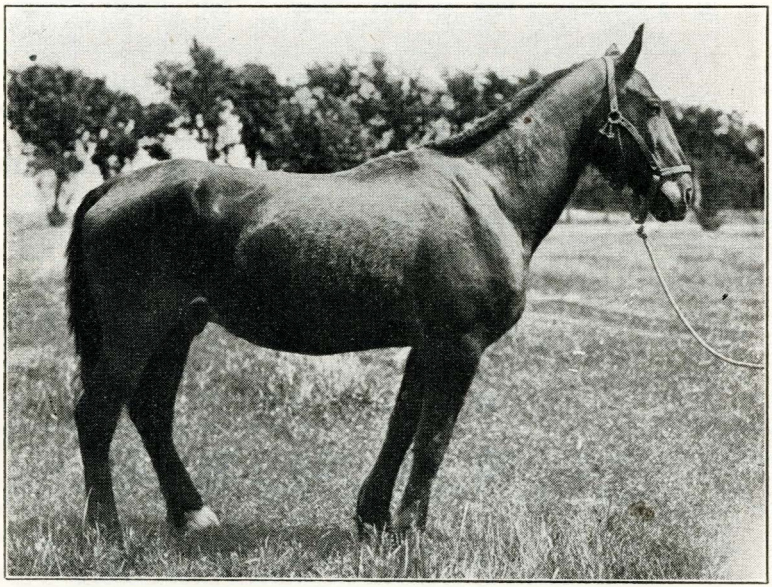

Fig. 6.—Horse No. 3 at the end of the experiment. A picture of mal-nutrition and ill-health.

Upon information derived from data in Table III, using actual weights of oat straw fed and calculated amounts of the constants consumed and voided, digestion coefficients were determined at the beginning of each of these feeding seasons. These coefficients are recorded in Table VIII.

The feces, collected during the periods devoted to the determination of digestion coefficients during these years, were analyzed and the results obtained are reported in Table IX.

The following tables show our results of composite analyses of the feces collected from each horse under experiment, during each ten-day interval of time between the close of the five-day trial for digestion coefficient determination and the close of the feeding season for the year in question. Not all of the feeding periods were of the same length. This feature was regulated by the nature of each particular season in the matter of early or late opening or proper facilities for letting the horses out for their recuperative out-door period. Conditions of labor and similar factors also played a part in this variation of feeding season's length.

In the year 1912, certain physical measurements of the horses used in the experiment were made and are recorded in Table VI. Similar measurements were taken during the four years and these are presented in Table XII. In order to condense this material several measurements have been taken for each year and distributed as well

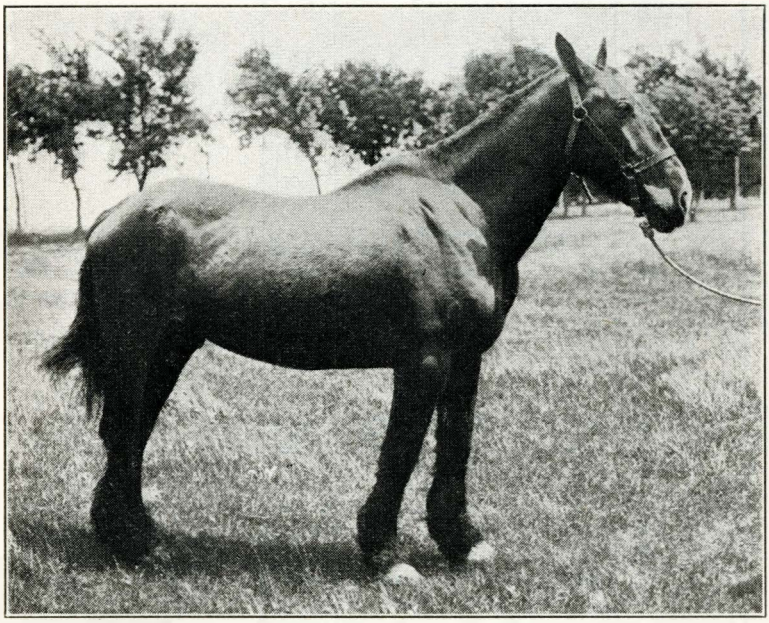

Fig. 7.—Horse No. 1 at the end of the experiment. Note emaciation, rough coat, and general appearance of run-down condition.

TABLE IX—ANALYSIS OF FECES—DIGESTION TRIAL PERIODS—1913-1916

		Air Dry Basis						Water-Free Basis				
Year	Horse	Water	Ash	Ether Extr.	Crude Fiber	Crude Prot.	N-Free Extr.	Ash	Ether Extr.	Crude Fiber	Crude Prot.	N-Free Extr.
1913	No. 1	4.76	11.36	4.22	35.51	5.64	38.51	11.93	4.43	37.29	5.92	40.43
	No. 2	3.01	11.40	4.10	35.83	5.50	40.16	11.76	4.23	36.94	5.67	41.40
	No. 3	3.17	10.97	3.97	36.74	5.06	40.09	11.33	4.10	37.94	5.23	41.40
	Ave.	3.98	11.24	4.10	36.03	5.40	39.59	11.67	4.25	37.39	5.61	41.08
1914	No. 2	3.33	8.82	3.46	36.32	4.69	43.38	9.12	3.58	37.57	4.85	44.88
	No. 3	3.40	8.86	3.52	35.92	4.68	43.62	9.17	3.64	37.18	4.84	45.17
	Ave.	3.37	8.84	3.49	36.12	4.69	43.50	9.15	3.61	37.38	4.85	45.03
1915	No. 2	3.66	7.86	3.75	34.25	6.56	43.92	8.16	3.89	35.55	6.81	45.59
	No. 3	2.74	7.96	4.22	33.40	6.87	44.81	8.18	4.34	34.34	7.07	46.07
	Ave.	3.20	7.91	3.99	33.83	6.72	44.37	8.17	4.12	34.95	6.94	45.83
1916	No. 2	2.85	8.74	2.70	40.23	5.00	40.48	8.99	2.82	41.41	5.14	41.64
	No. 3	2.87	9.37	2.76	39.18	5.50	40.32	9.64	2.84	40.34	5.66	41.51
	Ave.	2.86	9.06	2.73	39.71	5.25	40.40	9.32	2.83	40.88	5.40	41.58

TABLE X—COMPOSITE ANALYSIS OF FECES. TEN-DAY INTERVALS. 1913-1914.

Horse and Year	Constant	10 Days		20 Days		30 Days		40 Days		50 Days		60 Days	
		Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water Free
No. 1 1913	Water	76.28	....	74.19	....	76.19	....	75.08	....	73.98	....	75.88	....
	Ash	3.19	13.45	2.94	11.39	2.72	11.42	3.05	12.23	3.01	11.56	2.76	11.44
	Eth. Ext.	1.14	4.81	1.00	3.87	0.73	3.07	0.80	3.21	0.83	3.21	0.85	3.52
	Cr. Fiber	7.50	31.62	9.57	37.08	9.33	39.19	9.04	36.30	9.96	38.27	8.97	37.19
	Cr. Prot.	1.36	5.73	1.27	4.92	1.15	4.83	1.22	4.89	1.41	5.42	1.28	5.31
	N-Fr. Ex.	10.53	44.39	11.03	42.74	9.88	41.49	10.81	41.54	10.26	42.54	9.14	41.45
No. 2 1913	Water	73.58	....	73.77	....	75.84	....	76.24	....	77.19	....	75.15	....
	Ash	3.38	12.79	2.84	10.83	2.83	11.71	3.68	15.55	2.27	9.95	2.51	10.10
	Eth. Extr.	1.08	4.09	1.03	3.93	0.81	3.35	0.78	3.30	0.66	2.89	0.88	3.54
	Cr. Fiber	9.14	34.60	9.57	36.48	8.82	36.51	9.45	39.94	8.76	38.40	9.62	38.71
	Cr. Prot.	1.49	5.64	1.23	4.69	1.27	5.26	1.19	5.03	1.11	4.87	1.55	6.24
	N-F. Extr.	11.33	42.88	11.56	44.07	10.43	43.17	8.56	36.18	10.01	43.89	10.29	41.41
No. 3 1913	Water	77.48	....	78.42	....	77.02	....	78.97	....	77.66	....	79.45	....
	Ash	2.74	12.17	2.33	10.80	2.64	11.48	2.16	10.27	2.43	10.88	2.08	10.12
	Eth. Extr.	0.86	3.82	0.73	3.38	0.72	3.16	0.60	2.85	0.74	3.31	0.70	3.41
	Cr. Fiber	8.41	37.34	8.65	40.08	8.63	37.55	8.19	38.95	8.81	39.44	7.89	38.39
	Cr. Prot	1.15	5.11	0.91	4.22	1.06	4.61	1.07	5.09	1.28	5.73	1.03	5.01
	N-F. Extr.	9.36	41.56	8.96	41.52	9.93	43.20	9.01	42.84	9.08	40.64	8.85	43.07
Ave. 1913	Water	75.78	....	75.46	....	76.35	....	76.80	....	76.28	....	76.83	....
	Ash	3.10	12.80	2.70	11.01	2.73	11.54	2.96	12.68	2.57	10.80	2.45	10.55
	Eth. Extr.	1.03	4.24	0.92	3.73	0.75	3.19	0.73	3.12	0.74	3.14	0.81	3.49
	Cr. Fiber	8.35	34.52	9.26	37.88	8.93	37.75	8.89	38.40	9.18	38.70	8.83	38.10
	Cr Prot.	1.33	5.49	1.14	4.61	1.16	4.90	1.16	5.00	1.27	5.34	1.29	5.52
	N-F. Extr.	10.41	42.94	10.52	42.78	10.08	42.62	9.46	40.80	9.97	42.02	9.80	42.34
No. 2 1914	Water	74.50	....	76.00	....	75.52	....	75.87	....	74.70	....	76.55	....
	Ash	2.45	9.61	2.15	8.96	3.39	13.85	3.58	14.83	2.59	10.23	2.20	9.38
	Eth. Extr.	0.95	3.72	0.81	3.37	0.86	3.51	0.93	3.85	1.04	4.11	0.95	4.06
	Cr. Fiber	9.00	35.29	8.78	36.58	8.40	34.31	7.76	32.16	8.60	33.99	8.24	35.14
	Cr. Prot.	1.19	4.67	1.17	4.88	1.18	4.82	1.18	4.89	1.16	4.59	1.20	5.11
	N-F. Extr.	11.91	46.71	11.09	46.21	10.65	43.51	10.68	44.27	11.91	47.08	10.86	46.31

TABLE X—Concluded

No. 3 1914	Water	78.45	....	77.40	....	78.41	....	77.37	....	78.35	....	78.27	....
	Ash	2.06	9.55	1.92	8.50	2.73	12.64	2.94	12.99	1.91	8.82	2.04	9.38
	Eth. Extr.	0.67	3.11	0.75	3.32	0.70	3.24	0.79	3.49	0.69	3.18	0.88	4.08
	Cr. Fiber	7.91	36.71	8.64	38.23	7.78	36.03	7.80	34.47	8.65	39.96	7.71	35.47
	Cr. Prot.	1.05	4.87	1.10	4.87	1.04	4.82	1.04	4.59	1.05	4.85	1.11	5.10
	N-F. Extr.	9.86	45.76	10.19	45.08	9.34	43.27	10.06	44.46	9.35	43.19	9.99	45.97
Ave. 1914	Water	76.48	....	76.70	....	76.87	....	76.62	....	76.53	....	77.41	....
	Ash	2.26	9.58	2.04	8.73	3.06	13.25	3.26	13.91	2.25	9.53	2.12	9.38
	Eth. Extr.	0.81	3.42	0.78	3.35	0.78	3.38	0.86	3.67	0.87	3.65	0.92	4.07
	Cr. Fiber	8.46	36.00	8.71	37.41	8.09	35.17	7.78	33.32	8.63	36.98	7.98	35.31
	Cr. Prot.	1.12	4.77	1.14	4.88	1.11	4.82	1.11	4.74	1.11	4.72	1.16	5.11
	N-F. Extr.	10.89	45.74	10.64	45.65	10.00	43.39	10.37	44.37	10.63	45.14	10.43	46.14

		70 Days		80 Days		90 Days		110 Days		120 Days			
Horse and Year	Constant	Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free		
No. 1 1913	Water	77.95	....	76.25	....	76.74	....	73.93	....	....	....	....	....
	Ash	2.29	10.39	2.71	11.41	2.64	11.35	3.01	11.55	....	....	....	....
	Eth. Extr.	0.69	3.12	0.74	3.12	0.73	3.14	1.01	3.87	....	....	....	....
	Cr. Fiber	8.85	40.14	9.08	38.23	9.04	38.87	9.53	36.55	....	....	....	....
	Cr. Prot.	1.08	4.90	1.28	5.39	1.10	4.73	1.36	5.22	....	....	....	....
	N-F. Extr.	10.81	43.37	9.94	41.85	9.75	41.91	11.16	42.81	....	....	....	....
No. 2 1913	Water	77.23	....	78.89	....	77.65	....	77.68	....	....	....	....	....
	Ash	2.60	11.42	2.82	13.33	2.38	10.65	2.28	10.22	....	....	....	....
	Eth. Extr.	0.70	3.07	0.72	3.40	0.65	2.91	0.77	3.45	....	....	....	....
	Cr. Fiber	8.55	37.55	8.42	39.79	8.78	39.28	8.56	38.35	....	....	....	....
	Cr. Prot.	1.17	5.14	1.35	6.38	1.12	5.01	1.04	4.66	....	....	....	....
	N-F. Extr.	9.75	42.82	7.85	37.10	9.42	42.15	9.67	43.32	....	....	....	....

No. 3 1913	Water	80.41	....	76.46	....	80.45	....	78.99	....	....	....	....	....
	Ash	2.29	11.69	2.92	12.40	2.21	11.30	2.49	11.85	....	....	....	....
	Eth. Extr.	0.58	2.96	0.72	3.06	0.75	3.84	0.85	4.04	....	....	....	....
	Cr. Fiber	7.32	37.37	8.56	36.36	7.24	37.03	7.35	34.99	....	....	....	....
	Cr. Prot.	1.10	5.62	1.22	5.18	1.00	5.12	1.26	6.00	....	....	....	....
	N-F. Extr.	8.30	42.36	10.12	43.00	8.35	42.71	9.06	43.12	....	....	....	....
Ave. 1913	Water	78.53	....	77.18	....	78.28	....	76.87	....	....	....	....	....
	Ash	2.39	11.17	2.82	12.38	3.41	11.10	2.59	11.21	....	....	....	....
	Eth. Extr.	0.66	3.05	0.72	3.19	0.71	3.30	0.88	3.79	....	....	....	....
	Cr. Fiber	8.24	38.35	8.69	38.13	8.35	38.39	8.48	36.63	....	....	....	....
	Cr. Prot.	1.12	5.22	1.28	5.65	1.07	4.95	1.22	5.29	....	....	....	....
	N-F. Extr.	9.06	42.21	9.30	40.65	9.17	42.26	9.96	43.08	....	....	....	....
No. 2 1914	Water	76.90	....	77.81	....	77.76	....	79.02	....	79.54	....	....	....
	Ash	1.90	8.22	1.89	8.52	2.02	9.08	1.89	9.01	1.73	8.46	....	....
	Eth. Extr.	0.92	3.98	0.93	4.19	0.97	4.36	0.80	3.81	0.70	3.42	....	....
	Cr. Fiber	8.28	35.84	7.74	34.89	7.44	33.45	7.46	35.56	7.57	37.00	....	....
	Cr. Prot.	1.04	4.50	1.12	5.04	1.10	4.95	1.14	5.43	,1.05	5.13	....	....
	N-F. Extr.	10.96	47.46	10.51	47.36	10.71	48.16	9.69	46.19	9.41	45.91	....	....
No. 3 1914	Water	78.60	....	78.37	....	78.27	....	79.70	....	81.10	....	....	....
	Ash	2.02	9.44	1.96	9.06	2.10	9.66	1.86	9.16	1.49	7.89	....	....
	Eth. Extr.	0.92	4.29	0.90	4.17	0.92	4.24	0.79	3.89	0.65	3.45	....	....
	Cr. Fiber	7.31	34.17	7.44	34.39	7.45	34.29	7.07	34.83	7.07	37.40	....	....
	Cr. Prot.	1.10	5.14	1.10	5.09	1.15	5.29	1.17	5.76	0.97	5.13	....	....
	N-F. Extr.	10.05	46.96	10.33	47.29	10.11	46.52	9.41	46.36	8.72	46.13	....	....
Ave. 1914	Water	77.75	....	78.09	....	78.02	....	79.36	....	80.32	....	....	....
	Ash	1.96	8.83	1.93	8.79	2.06	9.37	1.88	9.09	1.61	8.18	....	....
	Eth. Extr.	0.92	4.14	0.92	4.18	0.95	4.30	0.80	3.85	0.68	3.44	....	....
	Cr. Fiber	7.80	35.01	7.59	34.64	7.[illegible]	33.87	7.27	35.20	7.32	37.20	....	....
	Cr. Prot.	1.07	4.82	1.11	5.07	1.13	5.12	1.16	5.60	1.01	5.13	....	....
	N-F. Extr.	10.51	47.21	10.42	47.33	10.4[illegible]	47.34	9.55	46.28	9.07	46.01	....	....

TABLE XI—COMPOSITE ANALYSIS OF FECES—TEN-DAY INTERVALS—1915-1916

Horse and Year	Constants	10 Days		20 Days		30 Days		40 Days		50 Days		60 Days	
		Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free
No. 2 1915	Water	78.82	.....	77.48	.....	78.68	.....	78.30	.....	77.75	.....	80.68	.....
	Ash	2.17	10.25	2.05	9.10	2.20	10.32	2.11	9.72	2.79	12.45	2.24	11.59
	Eth. Extr.	0.86	4.06	0.96	4.26	0.80	3.75	0.78	3.60	0.81	3.64	0.53	2.74
	Cr. Fiber	7.51	35.46	7.93	35.22	7.81	36.63	8.01	36.91	7.78	34.97	7.19	37.22
	Cr. Prot.	1.43	6.75	1.59	7.06	1.32	6.19	1.47	6.77	1.44	6.47	1.20	6.22
	N-F Extr.	9.21	43.48	9.99	44.36	9.19	43.11	9.33	43.00	9.45	42.48	8.16	42.23
No. 3 1915	Water	80.18	.....	80.64	.....	80.17	.....	80.83	.....	79.60	.....	83.48	.....
	Ash	2.16	10.90	1.88	9.71	2.20	11.09	2.09	10.90	2.48	12.16	1.97	11.94
	Eth. Extr.	0.82	4.14	0.83	4.28	0.83	4.19	0.75	3.91	0.81	3.97	0.43	2.60
	Cr. Fiber	6.86	34.71	6.59	34.04	7.06	35.60	6.86	35.79	7.29	35.73	6.10	36.92
	Cr. Prot.	1.33	6.71	1.25	6.46	1.30	6.56	1.39	7.25	1.29	6.32	0.97	5.87
	N-F Extr.	8.63	43.54	8.81	45.51	8.44	42.56	8.08	42.15	8.53	41.82	7.05	42.67
Ave. 1915	Water	79.50	.....	79.06	.....	79.43	.....	79.57	.....	78.68	.....	82.08	.....
	Ash	2.17	10.58	1.97	9.41	2.20	10.71	2.10	10.31	2.64	12.31	2.11	11.77
	Eth. Extr.	0.84	4.10	0.90	4.27	0.82	3.97	0.77	3.74	0.81	3.81	0.48	2.67
	Cr. Fiber	7.20	35.09	7.26	34.63	7.44	36.12	7.44	36.35	7.54	35.35	6.65	37.07
	Cr. Prot.	1.38	6.73	1.42	6.76	1.31	6.38	1.43	7.01	1.37	6.40	1.09	6.05
	N-F Extr.	8.92	43.51	9.40	44.94	8.82	42.84	8.71	42.58	8.99	42.15	7.61	42.45
No. 2 1916	Water	77.97	.....	79.29	.....	78.45	.....	79.77	.....	81.46	.....	79.44	.....
	Ash	2.11	9.57	1.89	9.12	2.12	9.85	2.15	10.63	1.93	10.41	2.43	11.82
	Eth. Extr.	0.63	2.90	0.55	2.65	0.55	2.56	0.52	2.57	0.40	2.16	0.38	1.85
	Cr. Fiber	8.29	37.67	7.95	38.38	8.50	39.50	7.92	39.15	7.32	39.48	7.75	37.64
	Cr. Prot.	1.27	5.67	1.21	5.84	1.38	6.41	1.25	6.18	1.18	6.37	1.28	6.23
	N-F Extr.	9.73	44.19	9.11	43.99	8.97	41.68	8.39	41.47	7.71	41.58	7.72	42.41

No. 3 1916	Water	79.53	.....	80.32	.....	79.76	.....	80.18	.....	81.54	.....	80.84	.....
	Ash	1.82	8.89	1.77	8.99	2.00	9.88	2.08	10.47	2.06	11.16	2.60	12.57
	Eth. Extr.	0.56	2.73	0.53	2.69	0.53	2.62	0.52	2.62	0.39	2.11	0.40	2.09
	Cr. Fiber	7.78	38.00	7.38	37.50	7.94	39.23	7.71	38.90	7.00	37.92	6.76	35.28
	Cr. Prot.	1.20	5.86	1.29	6.50	1.24	6.12	1.22	6.16	1.16	6.28	1.30	6.78
	N-F Extr.	9.17	44.52	8.71	44.26	8.53	42.15	8.29	41.85	7.85	42.53	8.10	42.28
Ave. 1916	Water	78.75	.....	79.81	.....	79.12	.....	79.98	.....	81.50	.....	80.14	.....
	Ash	1.97	9.23	1.83	9.06	2.06	9.87	2.12	10.55	2.00	10.79	2.52	12.70
	Eth. Extr.	0.60	2.82	0.54	2.67	0.54	2.59	0.52	2.60	0.40	2.14	0.39	1.97
	Cr. Fiber	8.04	37.84	7.67	37.94	8.22	39.37	7.82	39.03	7.16	38.70	7.26	36.49
	Cr. Prot.	1.24	5.77	1.25	6.20	1.31	6.27	1.24	6.17	1.17	6.33	1.29	6.51
	N-F Extr.	9.42	44.36	8.91	44.13	8.75	41.92	8.34	41.66	7.78	42.06	8.41	42.35

Horse and Year	Constants	70 Days		80 Days		90 Days		100 Days		110 Days		120 Days	
		Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free	Air-Dry	Water-Free
No. 2 1915	Water	78.97	.....	79.70	.....	77.98	.....	.....	.....	.....	.....	.....	.....
	Ash	2.40	11.41	2.09	10.30	2.51	11.40	.....	.....	.....	.....	.....	.....
	Eth. Extr.	0.67	3.19	0.56	2.76	0.71	3.22	.....	.....	.....	.....	.....	.....
	Cr. Fiber	7.96	37.85	7.84	38.62	7.78	35.33	.....	.....	.....	.....	.....	.....
	Cr. Prot.	1.36	6.47	1.26	6.21	1.44	6.54	.....	.....	.....	.....	.....	.....
	N-F Extr.	8.64	41.08	8.55	42.11	9.58	43.51	.....	.....	.....	.....	.....	.....
No. 3 1915	Water	79.44	.....	80.04	.....	80.34	.....	.....	.....	.....	.....	.....	.....
	Ash	2.55	12.40	2.25	11.27	2.31	11.73	.....	.....	.....	.....	.....	.....
	Eth. Extr.	0.70	3.41	0.56	2.81	0.63	3.21	.....	.....	.....	.....	.....	.....
	Cr. Fiber	6.84	33.27	7.58	37.98	6.90	35.10	.....	.....	.....	.....	.....	.....
	Cr. Prot.	1.49	7.24	1.28	6.41	1.31	6.67	.....	.....	.....	.....	.....	.....
	N-F Extr.	8.98	43.68	8.29	41.53	8.51	43.29	.....	.....	.....	.....	.....	.....

TABLE XI—Concluded

Ave. 1915	Water	79.21		79.87		79.16							
	Ash	2.48	11.91	2.17	10.79	2.41	11.57						
	Eth. Extr.	0.69	3.30	0.56	2.79	0.67	3 .22						
	Cr. Fiber	7.40	35.56	7.71	38.30	7.34	35.22						
	Cr. Prot.	1.43	6.84	1.27	6.31	1.38	6.61						
	N-F Extr.	8.81	42.38	8.42	41.82	9.05	43.40						
No. 2 1916	Water	78.30		80.84		78.10		78.32		77.49		78.01	
	Ash	2.25	10.37	1.99	10.39	2.14	9.77	2.08	9.59	2.55	11.33	2.48	11.28
	Eth. Extr.	0.52	2.40	0.36	1.88	0.45	2.05	0.40	1.85	0.45	2.00	0.43	1.96
	Cr. Fiber	8.04	37.05	7.10	37.05	8.51	38.86	8.38	38.65	8.32	36.96	8.34	37.93
	Cr. Prot.	1.43	7.97	1.56	8.14	1.64	7.49	1.23	5.67	1.68	7.46	1.65	7.50
	N-F Extr.	9.16	42.21	8.15	42.54	9.16	41.82	9.59	44.24	9.51	42.25	9.09	41.33
No. 3 1916	Water	81.83		78.61		81.68		82.00		80.39		80.33	
	Ash	2.01	11.06	2.08	9.72	1.83	9.99	1.83	10.17	2.32	11.83	2.13	10.83
	Eth. Extr.	0.41	2.26	0.45	2.10	0.31	1.69	0.32	1.78	0.37	1.89	0.37	1.58
	Cr. Fiber	6.90	37.98	8.32	38.90	7.24	39.52	6.98	38.78	7.38	37.63	7.62	38.74
	Cr. Prot.	1.42	7.81	1.60	7.48	1.30	7.10	1.25	6.95	1.46	7.44	1.30	6.61
	N-F Extr.	7.43	40.89	8.94	41.80	7.64	41.70	7.62	42.32	8.08	41.21	8.25	41.94
Ave. 1916	Water	80.07		79.73		79.89		80.16		78.94		79.17	
	Ash	2.13	10.72	2.04	10.06	1.99	9.88	1.96	9.88	2.44	11.58	2.31	11.06
	Eth. Extr.	0.47	2.33	0.41	1.99	0.38	1.87	0.36	1.82	0.41	1.95	0.40	1.92
	Cr. Fiber	7.47	37.52	7.71	37.98	7.88	39.19	7.68	38.72	7.85	37.30	7.98	38.34
	Cr. Prot.	1.58	7.89	1.58	7.81	1.47	7.30	1.24	6.31	1.57	7.45	1.48	7.06
	N-F Extr.	8.30	41.55	8.60	42.17	8.40	41.76	8.61	43.28	8.80	41.73	8.67	41.64

as possible throughout each feeding season. The blood counts which appear in Table XII were recorded as the average number of corpuscles observed in eight squares on each of two slides bearing the same sample, in the case of red corpuscles. The number recorded for the white corpuscles count is an average of from four to eight counts made upon four or more slides bearing the same sample.

At the conclusion of the work in 1916, horses No. 2 and No. 3 were destroyed. Their carcasses were examined by the veterinary department and autopsies embodying observations virtually parallel to those reported in the preceding pages were made. Numerous photographs of the animals, taken just prior to the close of the experiment, clearly portray the general appearance of emaciation and lack of condition of the horses after their experiences of the five years previous. These photographs are shown in Figures IV to VII and they plainly indicate the deterioration that took place in these animals since the period of their history represented by Figures I to III.

Photographs of various dissected portions of these two animals are also reproduced in Figures VIII to XI. Of these plates, the veterinary department makes the following report in reference to the bones of the hip, stifle, and fetlock joints as pictured in these figures:

"You will note on each of these photographs one or more dark areas, irregular in shape and varying in size. These darkened areas clearly indicate an erosion of the joint surfaces which was probably due to a ration deficient in certain important ingredients that was fed these horses."

The eroded areas referred to undoubtedly indicate a lack of mineral matter in the food necessary to the normal up-keep of the bony structure and to its proper lubrication. In other words, it is quite clearly indicated that the animal had been forced by an insufficient diet to sacrifice his bone tissue to the maintenance of the body as a whole.

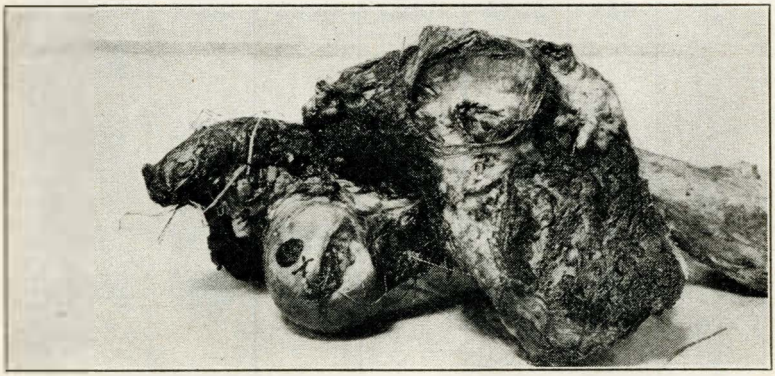

Fig. 8.—From horse No. 2. Note the circular eroded surface upon the ball of the hip joint bone.

TABLE XII—PHYSICAL MEASUREMENTS AND BLOOD COUNTS—1913-1916

Horse and Date		Blood Counts Erythroc.	Blood Counts Leucoc.	Weight lbs.	Girth	Triceps to Triceps	Withers to Rt. Pectoral	Withers to L. Pectoral	Rt. Hip to Left Glutial	Lft. Hip to Right Glutial	Left Thigh Ext. to Int.	Left Thigh Ant. to Post.	Right Thigh Ext. to Int.	Right Thigh Ant. to Post.
No. 1	Jan. 11	.....	.....	1097	7'0"	48.2"	79.0"	76.6"	41.9"	48.2"	24.0"	30.1"	24.5"	29.6"
1913	Feb. 15	8,580,000	.....	1097½	6'10½"	47.7"	77.7"	79.0"	41.0"	47.0"	21.8"	28.0"	22.0"	29.4"
	Apr. 18	8,938,000	.....	.....	6'8"	41.5"	74.5"	76.0"	40.6"	38.6"	15.5"	25.3"	19.5"	28.2"
No. 2	Jan. 11	5,842,000	.....	1115	6'6"	46.5"	75.0"	74.0"	42.9"	46.0"	21.5"	32.2"	25.1"	32.5"
1913	Feb. 15	7,306,000	.....	1140	6'4"	45.0"	75.2"	73.7"	42.8"	45.5"	20.8"	30.4"	24.5"	32.7"
	Mar. 18	.....	.....	1095	6'5"	43.5"	75.1"	74.0"	42.0"	42.5"	21.7"	35.3"	23.0"	31.0"
	Apr. 18	.....	.....	1075	6'2½"	40.0"	73.5"	73.6"	41.8"	41.8"	18.5"	21.9"	21.4"	27.7"
No. 3	Jan. 11	8,952,000	.....	1555	7'7½"	50.4"	82.9"	82.5"	49.0"	48.8"	28.2"	35.0"	28.2"	33.4"
1913	Feb. 15	9,094,000	.....	1580	7'6"	45.2"	82.0"	82.8"	46.0"	46.5"	27.5"	34.4"	28.4"	32.2"
	Mar. 18	8,982,000	.....	1517½	7'4½"	43.3"	82.3"	82.3"	45.3"	46.3"	25.5"	37.0"	22.6"	29.5"
	Apr. 18	.....	.....	1495	7'5"	43.5"	82.1"	79.8"	45.1"	45.1"	23.0"	31.1"	24.1"	28.0"
No. 2	Jan. 6	8,630,000	.....	1132½	6'7"	43.5"	75.0"	76.5"	55.0"	56.0"	24.5"	29.5"	24.5"	26.8"
1914	Feb. 18	6,250,000	.....	1135	6'7"	44.5"	75.5"	71.5"	55.0"	55.5"	25.5"	31.0"	26.5"	31.0"
	Mar. 13	9,614,000	.....	1130	6'6½"	43.5"	72.3"	76.0"	55.0"	54.7"	24.0"	30.5"	24.5"	31.5"
	Apr. 22	4,536,000	.....	1085	6'7"	42.0"	73.5"	76.5"	53.4"	53.5"	24.7"	29.3"	25.5"	29.5"
No. 3	Jan. 6	10,706,000	.....	1580	7'8"	48.0"	84.0"	83.0"	63.0"	63.0"	30.0"	32.5"	29.0"	34.0"
1914	Feb. 18	7,528,000	.....	1535	7'6"	47.5"	85.0"	85.0"	62.3"	64.0"	30.5"	33.4"	28.7"	34.0"
	Mar. 13	5,998,000	.....	1510	7'3"	45.8"	84.5"	85.0"	61.7"	63.5"	29.3"	34.5"	29.3"	34.3"
	Apr. 22	6,776,000	.....	1407	7'0"	42.0"	85.3"	85.5"	61.0"	62.0"	28.5"	31.3"	29.5"	33.5"
No. 2	Mar. 5	6,192,000	6800	1136	6'9"	42.5"	65.5"	68.8"	63.5"	64.7"	23.0"	34.5"	21.5"	32.0"
1915	Apr. 3	7,592,000	6720	1154	6'9½"	43.0"	68.3"	68.7"	63.5"	64.5"	22.0"	31.0"	19.5"	31.6"
	Apr. 28	6,060,000	6800	1112	6'9"	41.5"	68.1"	69.3"	64.2"	63.6"	22.6"	33.2"	20.0"	30.7"
	May 25	7,002,000	8600	1124	6'2¼"	42.0"	72.0"	68.5"	64.0"	65.0"	20.0"	32.0"	18.0"	31.0"

No. 3 1915	Mar. 5	7,272,000	9400	1521	7'9"	47.3"	70.5"	73.0"	78.0"	74.0"	24.5"	37.5"	23.5"	33.0"
	Apr. 3	7,660,000	8720	1496	7'6"	44.7"	75.3"	75.8"	71.0"	70.8"	22.5"	32.3"	24.0"	30.8"
	Apr. 28	5,408,000	9600	1424	7'3"	46.2"	76.5"	73.0"	70.0"	69.5"	26.2"	34.0"	22.7"	33.0"
	May 25	5,816,000	7000	1416	6'8"	42.0"	72.0"	73.0"	74.2"	70.0"	24.6"	33.2"	23.5"	35.1"
No. 2 1916	Feb. 14	....	....	1174	6'11"	42.7"	65.1"	64.3"	65.7"	69.7"	23.7"	26.5"	19.0"	27.5"
	Mar. 18	....	....	1132	6'9¾"	40.5"	62.5"	64.5"	68.5"	71.0"	21.3"	29.5"	18.3"	28.0"
	May 1	....	....	1070	6'8¼"	38.1"	64.0"	65.5"	70.0"	70.5"	17.8"	29.0"	20.0"	28.3"
	Jun. 10	....	....	1048	6'¼"	35.5"	69.5"	67.5"	70.0"	70.0"	19.7"	28.5"	17.0"	28.3"
No. 3 1916	Feb. 14	....	....	1462	7'5"	40.2"	70.3"	74.7"	75.0"	76.7"	20.5"	36.0"	23.0"	35.9"
	Mar. 18	....	....	1412	7'6"	43.0"	70.0"	74.7"	74.0"	74.5"	21.3"	34.3"	21.5"	33.5"
	May 1	....	....	1294	7'0"	39.0"	66.7"	71.3"	74.3"	73.0"	20.0"	32.8"	20.7"	34.0"
	Jun. 10	....	....	1282	6'4"	37.5"	71.5"	73.0"	75.7"	77.0"	19.0"	31.4"	23.8"	27.0"

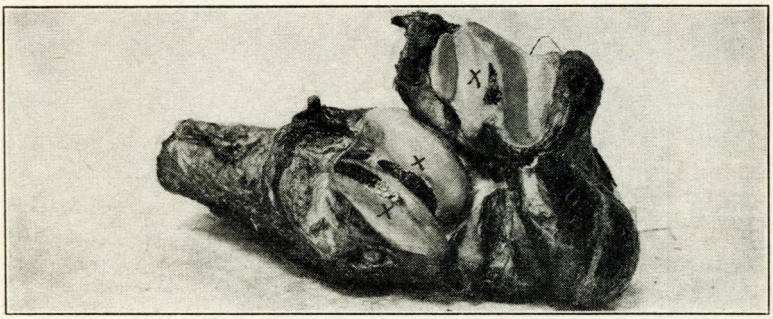

Fig. 9.—From horse No. 2. Note eroded areas on the stifle joint.

The essential difference between observations made at the first of the experiment and the conditions obtaining at its close lies in the development of a marked tendency in Horse No. 3 toward thrush, and in Horse No. 2 toward ringbone.

CONCLUSIONS

Certain marked and valuable items of information have been derived from this experiment as conducted. Of these items, the following are outstanding:

1. From a survey of the tables having to deal with physical measurements during the several years covered by the experiment, it is noted that at a time which varies somewhat but which occurs usually from thirty to forty days after the opening of each year's feeding season, the animals seem to improve in physical particulars, including in some cases the blood count, during several days. The change that has occurred in their diet, even though such change is toward loss of balance in the ration, appears to result in temporary improvement. After this temporary up-trend in physique, the reaction is rapid and notable to the end of the feeding season.

2. Despite this fact, a steady loss in weight is found to obtain from the first to the last of the season.

3. As might be expected, the unbalanced character of the ration fed in this experiment produces, in a general way at least, and despite some marked exceptions as noted in the tables, a diminution in the number of red blood corpuscles, with a reverse effect upon the number of leucocytes present in the blood. Apparently, as the physical condition of the animal becomes sub-normal, the leucocytes almost automatically increase as a safeguard against the conditions which are threatened by a lack of balanced nourishment.

4. A comparison of the digestion coefficients obtained during the first year of the experiment brings out a striking change during the period of feeding, not only in their general average but in the individual cases. There was a marked fall in these horses' ability to digest all types of food, with the single exception of that type of nutrient which was to be relied upon most for energy upkeep—the

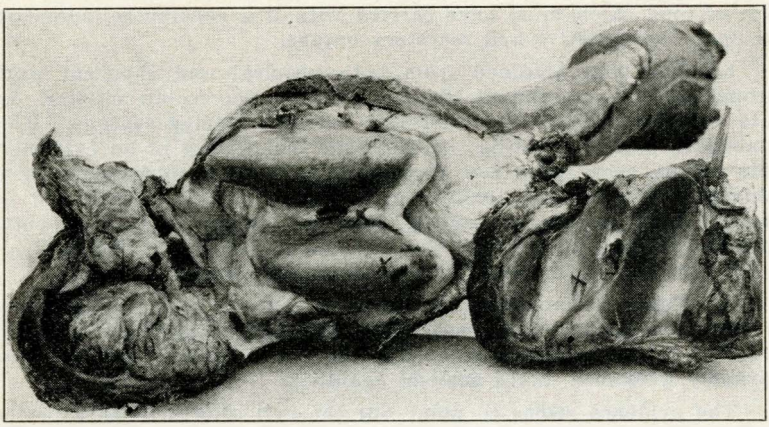

Fig. 10.—From horse No. 3. Note eroded areas in the stifle joint.

fats. In the case of this one nutrient, the digestive capacity was in two instances and on the average, more than doubled. This occurred in the face of a heavy decrease in the digestion coefficient of the ration, taken as a whole.

5. The tables covering the chemical examination of voided nutrients, as collected and analyzed in the composite, when compared with the observation made in Table IV show that while the ability of the animals to digest their food became consistently lower during a given experimental period, the feces indicate a fairly constant rate of elimination of the nutrients, with the single exception of the ether extract. Evidently a constantly increasing bulk of food was eaten in order to make possible the retention of sufficient nutrients to maintain normal body condition. This observation is amply substantiated by a glance at the amounts of feeding material eaten during the two digestion coefficient trials of 1912. Such increase in the

Fig. 11.—From horse No. 3. Note triangular eroded surfaces on the fetlock joint.

bulk of food eaten must have carried with it a constantly increasing tax upon the digestive and secretory organs.

6. The data obtained from both physical and chemical work throughout the experiment show a steadily decreasing vitality, despite the long period of recuperation between feeding seasons. This establishes beyond question the fact that the feeding of an extremely wide ration, even for a few months of each year, works permanent damage to the general health and efficiency of the animal. In no one of these periods of feeding does the animal appear to enter upon the feeding period with the measure of well-being that was his at the opening of the work of the preceding season.

7. There is ample evidence to show that, in such circumstances as those produced in this experiment, the animal sacrifices his bone structure to the maintenance of life, tending to become spavined and markedly weakened in his skeletal condition.

The evidence seems to point out the evil effects to be expected from a custom—followed quite extensively in some localities even to this day—of allowing horses to have access to straw only during several months of the year, especially during those months wherein the animals are in comparative idleness. Particularly is this practice to be condemned when these are months of great demand for heat-producing feeding materials.

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