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A. B. CONNER, DIRECTOR
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DIVISION OF CHEMISTRY

Digestibility by Sheep of the Constituents of the Nitrogen-Free Extract of Feeds

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS
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The sugars, starch, and other constituents of feeding stuffs were studied by means of chemical analyses and digestion experiments with sheep, for the purpose of ascertaining if there was any relation between the content in these materials and their feeding values, and also in order to secure more definite information regarding the composition of the feeds and the digestibility of their chemical constituents. In general, feeds of high feeding value have a high content either of starch, or of sugars and starch combined, or a high content of protein. Analyses and about 40 digestion experiments are reported. Analyses and digestion experiments on 56 feeds are averaged. The occurrence and the digestibility are briefly discussed for the sugars, starches, total pentosans, pentosans in nitrogen-free extract, pentosans in crude fiber, and the residual nitrogen-free extract.

CONTENTS

BULLETIN NO. 418 NOVEMBER, 1930

DIGESTIBILITY BY SHEEP OF THE CONSTITUENTS OF THE NITROGEN-FREE EXTRACT OF FEEDS

G. S. FRAPS

The ordinary chemical analysis of feeds deals with groups of compounds. The protein, fat, crude fiber, and ash are each mixtures of definite chemical substances, which vary both in character and in relative proportions from one feed to another. The individual substances vary in digestibility, in value to the animal organism, and in other properties. The consequence is that the same groups of constituents in different feeds have different nutritive values. The differences may result in different degrees of digestibility, and in different values of the same quantity of digested material, for the purposes of production of flesh, fat, or milk, or for maintenance of the animal body.

While considerable work has been done on the constituents of protein and fats, the investigations on the constituents of the nitrogen-free extract of feeds, with the exception of pentosans, have been more limited in number. These include the work of Frear on timothy hay (6), and Headden (7) on various Colorado feeds. Street and Bailey (9) have reported on the carbohydrates of the soy bean and Peterson and Churchill (10) on those of the navy bean (10). The work here reported was done in connection with ordinary digestion experiments on sheep, and is intended to supplement the work already reported, and is a continuation of that published in Bulletin No. 172 of the North Carolina Agricultural Experiment Station and Bulletins Nos. 104, 175, 196, and 290 of the Texas Agricultural Experiment Station (1, 2, 3, 4, 5).

The great differences in the productive values of feeding stuffs depend not only upon differences in digestibility, but no doubt also upon differences in chemical composition. A pound of digestible nitrogen-free extract in hays and fodders is much less valuable to the animal than a pound digested from feeds such as corn. This is no doubt caused by differences in the chemical constituents. Starch, being easily digested, has a higher value to the animal than other less soluble compounds which yield hexoses by hydrolysis. These studies of the composition and digestibility of the nitrogen-free extract of feeds were undertaken in the hope that they would throw some light on the reasons for the differences in the feeding values of some of these feeds.

Table 1.—Average percentage composition of feeds

	Number averaged	Reducing sugars	Polysaccharoses	Starch	Pentosans in N. F. E.	Residual N. F. E.	Total pentosans	Pentosans in C. F.
Alfalfa hay	9	1.92	1.65	1.90	9.21	22.44	14.00	4.91
Alfalfa meal	4	2.33	1.45	1.23	10.13	24.07	14.70	4.59
Alfalfa hay and meal	13	2.05	1.58	1.69	9.49	22.94	14.21	4.81
Beans, Jack	1	0.07	1.86	32.59	8.36	5.13	8.86	0.50
Beans, pinto	1	0.12	5.77	22.22	7.30	22.80	7.53	0.44
Bermuda hay	2	1.39	1.57	4.01	18.65	24.07	22.53	3.89
Broom corn seed, ground	1	1.14	0.24	25.40	13.70	19.27	15.83	2.13
Corn grain	1	0.44	0.72	62.82	5.61	1.82	5.81	0.20
Corn bran	1	1.14	1.92	26.79	19.09	15.69	23.09	4.00
Corn cobs (ground)	1	0.49	0.34	2.39	26.31	23.18	33.07	6.76
Corn silage (dried)	1	2.41	0.13	6.02	16.96	23.52	20.96	4.00
Cottonseed, whole pressed	3	0.06	3.73	0.00	11.14	12.51	14.40	2.99
Cottonseed hulls	3	0.10	0.18	1.14	18.74	14.87	23.68	4.71
Cottonseed meal	5	0.26	5.60	0.04	7.96	10.59	9.42	1.46
Dolichos lablab hay	1	0.65	0.54	6.63	8.29	17.50	13.29	5.00
Darso seed	1	0.76	0.30	56.24	3.14	10.31	3.36	0.22
Feterita forage	1	0.58	0.19	3.72	17.12	20.28	22.46	5.34
Feterita seed	1	0.35	0.77	60.05	3.19	5.66	3.39	0.20
Flax plant by-product	1	0.25	0.20	1.66	12.50	18.27	20.37	7.87
Goose grass	1	0.39	0.14	0.25	19.74	25.24	24.55	4.81
Kafir chops	1	0.58	0.34	65.14	4.25	0.22	4.45	0.20
Kafir forage	1	1.01	0.55	2.36	17.94	23.89	23.26	5.32
Kafir head chops	1	0.48	0.90	54.18	6.75	5.11	8.75	2.00
Kafir head stems	*1*	*1.69*	*0.25*	*8.91*	*22.67*	*23.23*	*26.01*	*3.34*
Linseed meal	2	0.35	2.75	3.17	9.70	20.06	11.11	1.42
Mesquite beans (in pods)	1	1.55	13.73	4.65	10.85	16.77	16.18	5.34
Mesquite grass	1	0.58	0.10	1.23	18.23	22.12	21.53	3.30
Milo chops	1	0.57	0.63	54.21	10.06	3.75	10.56	0.50
Milo forage	1	0.55	0.37	1.64	18.65	23.77	23.73	5.08
Milo (grain)	4	1.18	0.32	59.01	4.12	6.79	4.32	0.20
Moth bean hay	1	0.66	0.29	4.55	6.76	22.01	11.76	5.00
Oak leaves, live	1	1.07	0.04	0.61	9.11	34.48	13.22	4.11
Oats, rolled (oat groats)	1	0.19	1.13	52.43	3.63	8.00	3.66	0.04
Oats, whole, 12% fibre	1	1.00	0.79	36.55	10.32	9.41	11.65	1.33
Oats, whole, low grade (17% fibre)	1	1.27	0.65	27.87	15.95	9.23	18.15	2.20
Oat hull clippings	*3*	*1.04*	*0.21*	*7.36*	*18.46*	*18.06*	*21.45*	*3.31*
Oat meal mill by-product	2	1.03	0.60	10.91	23.17	15.33	26.93	3.89
Peanut hay	4	1.89	2.78	4.29	8.27	26.92	11.80	3.53
Peanut hulls	3	0.93	1.41	1.99	4.56	11.25	16.12	11.56
Peanut kernels	1	0.19	5.11	4.56	2.33	1.16	2.69	0.36
Peanut vines	2	4.97	1.91	5.97	7.07	28.78	11.07	4.00
Peat	1	0.09	0.03	0.53	2.25	32.00	2.62	0.37
Prairie hay	5	1.89	0.76	2.12	16.68	25.11	13.99	10.74
Rhodes grass hay	2	1.67	0.93	1.01	19.15	19.94	23.46	4.31
Rice bran	2	1.25	5.54	17.52	8.04	9.17	9.92	1.90
Rice hay	1	1.17	0.82	6.80	15.30	15.82	18.91	3.61
Rice hulls	2	0.20	0.27	2.63	9.53	15.36	16.26	6.74
Rice polish	3	1.77	4.04	41.15	4.94	.....	5.14	0.20
Rice, rough	3	0.36	0.56	60.01	5.15	0.02	5.65	0.50
Shallu forage	1	0.63	0.39	1.47	20.64	22.44	26.07	5.43
Sorgo forage (accuff)	1	0.17	0.39	1.50	19.75	22.05	25.14	5.39
Sorghum hay	2	8.50	0.48	3.55	13.92	21.86	18.92	5.00
Sorghum seed (red top)	1	0.86	1.17	49.90	3.96	16.89	4.31	0.35
Sorghum silage (dried)	1	3.79	0.03	23.56	10.26	20.39	15.26	.....
Silage (dried) sorghum and cow-pea	1	2.61	1.82	15.70	11.59	21.57	16.59	.....
Sudan grass hay	5	3.15	0.89	2.23	15.29	20.98	19.72	4.43
Tabosa grass	2	1.53	0.97	2.50	17.88	22.98	22.88	5.00
Velvet beans	1	3.26	2.58	25.58	6.28	12.25	7.15	0.87
Velvet beans, pods	1	0.49	0.02	0.86	12.82	33.90	15.99	3.34
Wheat, whole	1	0.82	2.38	51.64	7.33	8.36	7.83	0.50
Wheat bran	1	0.79	4.89	15.53	20.24	12.92	20.94	0.70
Wheat gray shorts	2	1.21	5.11	28.92	13.63	8.25	14.07	0.45
Wheat white shorts	1	0.62	1.80	52.15	6.65	6.03	6.75	0.10

METHOD OF WORK

The materials used were secured in the digestion experiments with sheep, discussed in Bulletins Nos. 291, 315, and 402 of this Experiment Station. The feeds were fed alone or in combination, as there described.

The sugars were extracted with 50 per cent alcohol, and estimated by the Munsen and Walker method. Starch was made soluble by diastase, on material previously extracted with ether and alcohol, and the analysis was completed in the usual way. Some gums, if present, would be included in the starch. Total pentosans were determined in the usual way, by conversion into furfural followed by precipitation with phloroglucinol. Pentosans in crude fiber were estimated in the crude fiber prepared from a 3-gram sample. The total pentosans less that in the crude fiber gives the pentosans in the nitrogen-free extract. The reducing sugars, non-reducing sugars, starch and pentosans in the nitrogen-free extract, were added together and the sum subtracted from the total nitrogen-free extract. The difference is here called the residual nitrogen-free extract. The residual nitrogen-free extract is the amount of total nitrogen-free extract remaining after the sugars, starches, and pentosans in the nitrogen-free extract have been deducted.

COMPOSITION OF FEEDS

The ordinary analysis of the feeds is given in Bulletins Nos. 291, 315, and 402. Table 1 contains the sugars, starch, and other constituents of the feeds used in the experiments here reported. It also includes those used in previous experiments, already reported, for purposes of comparison, together with some additional analyses.

The feeds known to be of high feeding value are characterized by a high content of sugars and starch, or, if the starch content is not high, by a high percentage of protein. The residual nitrogen-free extract, while appreciable, is low compared with the other classes of feed. The roughages or feeds of low feeding value are generally characterized by a high content of pentosans and of residual nitrogen-free extract. The nature of the residual nitrogen-free extract of these feeds is a good subject for further study.

With respect to sugar, the feeds studied may be grouped as follows:

Less than 2 per cent sugar—broom corn seed, corn cobs, cottonseed hulls, cottonseed meal from heated seed, darso seed, flax plant by-product, goose grass, kafir head stems, live oak

leaves, milo seed, oat groats, whole oats, oat hull clippings, oat meal mill by-product, peanut shells, rice hulls.

From 2 per cent to 5 per cent sugar—alfalfa, cottonseed feed, cottonseed meal, linseed meal, sacchuista grass, sorgo seed, wheat white shorts.

Over 5 per cent sugar—mesquite beans in pods (15.28 per cent of sugar), rice bran, rice polish, velvet beans in pod, velvet beans, whole wheat, whole bran, wheat gray shorts.

With respect to starch, the feeds studied may be grouped as follows:

Less than 2.5 per cent starch—alfalfa, corn cobs, cottonseed feed, cottonseed hulls, goose grass, live oak leaves, mesquite beans, peanut hulls, rice hulls.

From 2.5 per cent to 25 per cent starch—commercial kafir head stems, linseed meal, mesquite beans in pod, oat hull clippings, oat meal mill by-product, pinto beans, velvet beans in pods, rice bran, wheat bran.

From 25 per cent to 50 per cent starch—broom-corn seed, whole oats, rice polish, sorghum seeds, velvet beans, wheat gray shorts.

Over 50 per cent starch—darso seed, milo seed, oat groats, whole wheat, wheat white shorts.

Pentosans are low in the concentrated feeds and high in hays and fodders. Feeds containing less than 6 per cent of total pentosans include corn, darso seed, feterita seed, kafir seed, milo seed, oat groats, peanut kernels, rice polish, rough rice, and sorghum seed. Feeds with 6 to 11 per cent pentosans include beans, cottonseed meal, kafir head chops, milo head chops, rice bran, velvet beans, whole wheat, and wheat white shorts.

Alfalfa, dolichos lablab, linseed meal, moth bean hay, whole oats, peanut hay, and wheat gray shorts contain 11 to 14 per cent of pentosans. Cereal hays and other roughages in general contain over 20 per cent of pentosans.

COEFFICIENTS OF DIGESTIBILITY

The coefficients of digestibility secured are given in Table 3. Average coefficients of digestibility for the work given in this and previous bulletins, are given in Table 2. Single experiments (usually with two sheep) are also given, so that the table presents a complete summary of the digestion coefficients secured with sheep. Sugars and starches have almost invariably a high digestibility. In a few cases, the digestibility appears to be low, but this is in feeds which have a low content of sugar or starch. It is also questioned if the reducing substances found in the excrement really consists of sugar. As pointed out previously (1),

Table 2.—Average digestion coefficients, with sheep.
Each experiment usually with two sheep

	Number of experiments averaged	Reducing sugars	Polysaccharoses	Starch	Pentosans in N. F. E.	Residual N. F. E.	Total pentosans	Pentosans in C. F.
Alfalfa hay	16	97	98	86	56	69	53	41
Alfalfa meal	4	95	96	81	60	70	58	52
Cottonseed hulls	7	52	69	44	78	24	76	57
Cottonseed meal	5	73	99	.....	95	53	94	79
Cold pressed cottonseed	3	72	99	.....	86	41	82	13
Bermuda hay	2	97	99	90	44	48	44	43
Broomcorn seed, ground	1	77	100	84	37	20	32	5
Corn bran	1	99	100	99	93	65	90	.....
Corn, Argentine	1	100	100	93	97	50	91	23
Corn cobs	1	84	79	83	53	34	55	65
Corn silage	1	99	94	97	77	68	56	72
Dalochos lablab hay	1	94	100	92	49	63	56	68
Feterita forage	1	94	97	89	64	54	63	71
Feterita seed	1	100	100	99	91	73	85	50
Flax plant by-product	2	30	69	.....	2	.....	3	5
Goose grass	1	79	100	100	44	22	42	33
Jack beans	1	100	100	100	97	78	95	.....
Kafir chops	1	95	100	97	89	0	75	.....
Kafir head chops	1	100	88	88	64	3	57	.....
Kafir head stems	1	91	95	94	51	23	48	32
Kafir forage	1	94	97	95	43	42	54	46
Linseed meal	1	78	99	97	84	79	78	44
Live oak leaves	1	100	100	100	1	28	13	38
Mesquite beans	2	87	79	97	58	48	52	43
Milo head chops	1	100	100	99	92	3	70	.....
Milo forage	1	81	79	60	57	41	62	68
Moth bean fodder	1	85	94	93	47	63	59	74
Milo	4	90	64	99	90	77	79	33
Oats	2	89	98	100	74	54	68	46
Oat hull clippings	2	47	53	93	65	29	64	54
Oat meal mill by-product	2	96	94	100	35	22	33	20
Peanuts, whole	1	84	100	100	50	.....	40	28
Peanut hay	4	98	100	91	66	62	60	58
Peanut vines	1	52	88	92	64	76	.....	66
Peanut hay with nuts	1	84	100	100	50	0	40	28
Peanut hulls	2	97	100	88	10	64	24	40
Pinto beans	1	97	100	99	90	86	85	35
Prairie hay	6	97	94	77	52	35	50	43
Rhodes grass hay	2	97	97	61	62	63	62	64
Rice bran	2	95	100	100	60	38	47	2
Rice hay	1	94	95	86	46	26	46	50
Rice polish	3	98	99	100	88	44	76	19
Rice hulls	1	.....	81	88	43	24	49	43
Rough rice	3	88	100	99	34	.....	52	.....
Shallu forage	1	94	100	73	56	41	58	65
Sorgo forage accuff	1	74	96	67	57	32	74	55
Sorghum hay	2	99	93	83	49	48	65	55
Silage, sorghum, and cowpeas	1	95	97	90	28	32	36	.....
Sorghum silage	1	98	100	92	40	46	49	.....
Sudan grass	5	99	84	77	53	38	55	58
Tabosa grass	2	98	99	79	48	36	49	53
Velvet beans, cracked and pods	1	98	98	96	97	90	95	87
Wheat, whole	1	98	100	99	96	95	95	86
Wheat bran	1	91	15	26	22	79	26	100
Wheat gray shorts	2	96	99	100	85	40	85	46
Wheat white shorts	1	95	99	100	95	74	93	100

other materials may give rise to the small amount of reduction which occurs.

The digestibility of the pentosans in the nitrogen-free extract varies according to the nature of the feed in which it is contained. The digestibility is especially low with oatmeal mill by-product. As a rule, the pentosans in the nitrogen-free extract are digested to a greater extent than the total pentosans or the pentosans in the crude fiber. The total pentosans in hays and fodders are generally digested to the extent of around 50 to 60 per cent. Corn silage, corn cobs, kafir-head chops, kafir-head stems, rice bran, rice hulls, and rough rice come in the same group. The pentosans of certain feeds have a high digestibility; this group includes cottonseed meal, cottonseed hulls, corn bran, jack beans, linseed meal, milo, pinto beans, rice polish, velvet beans in pods, whole wheat, wheat gray shorts, and wheat white shorts. The pentosans of some feeds have a low digestibility; these include broom-corn seed, flax plant by-product, live oak leaves, and peanut hulls.

The pentosans in the crude fiber are generally digested to a less extent than the total pentosans, and the pentosans in the nitrogen-free extract to a greater extent. This is exactly what one would expect. The pentosans in the nitrogen-free extract have a high digestibility in cottonseed meal, corn bran, corn, feterita seed, jack beans, kafir, cold-pressed cottonseed, linseed meal, milo head chops, milo, pinto beans, rice polish, velvet beans in pod, whole wheat, wheat gray shorts, and wheat white shorts.

The residual nitrogen-free extract in hays and fodders is generally digested to a greater extent than the pentosans, in which the pentosans have a digestibility around 50 to 60 per cent. The digestibility of the residual nitrogen-free extract is generally lower than that of the pentosans in such feeds as have high digestion coefficients for pentosans. Corn cobs was the only exception to this rule; the pentosans in the crude fiber were digested to a greater extent than those in the nitrogen-free extract. There is a possibility that fermentation in the animal may change crude fiber so as to be partly soluble in $1\frac{1}{4}$ per cent acid or alkali, thereby causing it to appear in the nitrogen-free extract. This change may have occurred with the corn cobs.

The residual nitrogen-free extract has a low digestibility in cottonseed hulls, broom-corn seed, corn cobs, goose grass, kafir chops, kafir head chops, kafir head stems, live oak leaves, milo head chop, oatmeal mill by-product, peanut hay with nuts, rice hay, rice hulls, and rough rice.

Table 3—Individual digestion coefficients

Lab. No.			Reducing sugars	Polysaccharoses	Starch	Pentosans in N. F. E.	Residual N. F. E.	Total pentosans	Pentosans in C. F.
21948–9	Alfalfa D. E. 154	Sheep No. 3	96.6	97.6	88.5	66.1	72.0	60.2	48.6
		Sheep No. 13	97.4	98.3	98.4	63.7	70.2	59.1	49.8
20715–6	Alfalfa meal D. E. 144	Sheep No. 3	99.5	97.3	43.2	55.8	75.0	57.2	61.3
		Sheep No. 5	99.2	95.3	65.1	66.7	74.7	63.3	53.7
18685–6	Alfalfa hay D. E. 122	Sheep No. 1	96.5	100.0	96.8	66.9	74.2	58.6	42.9
		Sheep No. 2	96.3	100.0	99.0	70.5	72.4	63.8	49.2
19018–9	Alfalfa meal D. E. 131	Sheep No. 1	97.2	96.9	87.4	65.4	74.2	63.5	60.0
		Sheep No. 2	96.6	99.0	96.8	63.3	71.1	62.2	60.3
19421–2	Alfalfa meal D. E. 134	Sheep No. ..	97.3	98.5	100.0	55.7	69.3	52.8	47.7
21948–9	Alfalfa D. E. 170	Sheep No. 3	97.8	94.1	90.0	69.5	61.1	61.5	45.6
		Sheep No. 15	93.9	100.0	89.9	57.8	64.6	54.7	48.5
21824	Alfalfa meal D. E. 153	Sheep No. 13	96.8	98.3	100.0	58.9	67.4	56.2	40.0
		Sheep No. 15	79.0	81.4	55.0	56.0	57.6	52.4	43.0
22927	Broom corn seed, ground (with alfalfa)	Sheep No. 3	73.5	100.0	100.0	40.9	19.2	33.4	0
		Sheep No. 15	79.6	100.0	68.9	32.9	21.6	29.8	10.8
20190	Corn cobs (with alfalfa meal) D. E. 141	Sheep No. 3	90.0	64.2	95.2	53.9	31.3	56.6	67.9
		Sheep No. 5	78.7	94.6	70.9	52.6	36.8	54.3	61.5
20186–7	Cottonseed hulls (with alfalfa) D. E. 146	Sheep No. 13	19.1	100.0	97.7	89.8	33.8	82.6	57.5
		Sheep No. 15	0	100.0	81.3	87.8	54.0	85.2	73.9
22166–7	Cottonseed hulls D. E 164	Sheep No. 3	77.6	35.5	0	55.6	20.8	52.6	38.2
		Sheep No. 13	0	100.0	0	81.5	40.3	78.7	65.6
22166–7	Cottonseed hulls (with alfalfa) D. E. 165	Sheep No. 15	100.0	39.3	0	84.2	38.0	79.4	57.1
22166–7	Cottonseed hulls (with alfalfa) D. E. 168	Sheep No. 3	28.1	29.4	100.0	86.4	11.4	83.3	71.8
		Sheep No. 15	100.0	89.7	100.0	87.2	25.9	86.1	84.0
22166–7	Cottonseed hulls D. E. 171	Sheep No. 3	0	69.3	0	82.0	3.1	77.7	57.1
		Sheep No. 15	0	66.9	0	58.9	0	54.9	35.9
20135–6	Cottonseed meal (with cottonseed hulls) D. E. 147	Sheep No. 13	0	97.4	0	100.0	0	100.0	100.0
		Sheep No. 15	16.7	98.3	0	100.0	0	100.0	100.0
22131–2	Cottonseed meal, heated seed (with alfalfa) D. E. 157	Sheep No. 13	77.5	100.0	0	99.7	77.7	100.0	100.0
		Sheep No. 15	87.2	99.7	0	99.2	78.1	98.0	100.0
22146–7	Cottonseed meal, heated seed (with alfalfa) D. E. 158	Sheep No. 3	46.4	99.9	100.0	92.9	71.5	90.9	88.8
		Sheep No. 15	100.0	98.8	100.0	97.3	85.8	100.0	100.0
22187–8	Cottonseed meal, heated seed (with alfalfa) D. E. 160	Sheep No. 3	76.6	100.0	0	91.0	45.1	89.4	90.8
		Sheep No. 13	100.0	96.5	0	93.4	71.3	92.8	99.8
22215–6	Flax plant by-product D. E. 162	Sheep No. 13	23.7	16.9	0	0	0	0	2.0
		Sheep No. 15	47.3	60.4	.....	9.4	.....	12.8	18.1
21798–9	Goose grass D. E. 152	Sheep No. 13	78.8	100.0	100.0	43.7	22.4	41.7	32.9
22115–6	Linseed meal (with alfalfa) D. E. 156	Sheep No. 13	100.0	100.0	100.0	100.0	100.0	100.0	100.0
		Sheep No. 15	74.2	98.8	100.0	83.9	75.5	76.3	36.5
21206–7	Live oak leaves (with alfalfa) D. E. 150	Sheep No. 13	100.0	100.0	100.0	0.8	28.3	12.6	38.2
21176–7	Mesquite beans (with alfalfa) D. E. 148	Sheep No. 13	88.0	100.0	100.0	79.1	56.8	67.7	44.1
		Sheep No. 15	94.4	100.0	100.0	74.1	65.3	64.5	44.4
21964	Mesquite beans (with alfalfa) D. E. 155	Sheep No. 3	76.2	55.0	100.0	43.3	34.7	42.5	42.5
		Sheep No. 13	88.4	60.9	87.5	34.0	33.6	34.7	42.8
19001–2	Milo, whole (with alfalfa) D. E. 130	Sheep No. 1	93.2	100.0	97.8	88.3	73.1	69.2	0
		Sheep No. 2	91.9	93.1	96.7	100.0	54.3	78.3	0

Table 3—Individual digestion coefficients—Continued

Lab. No.			Reducing sugars	Polysaccharoses	Starch	Pentosans in N. F. E.	Residual N. F. E.	Total pentosans	Pentosans in C. F.
23160	Milo (with alfalfa) D. E. 176	Sheep No. 3	87.3	100.0	97.8	100.0	78.1	100.0	100.0
		Sheep No. 15	96.8	100.0	99.7	100.0	100.0	100.0	100.0
24414	Milo (with alfalfa) D. E. 186	Sheep No. 3	59.0	100.0	.....	.....	.....	76.1	.....
		Sheep No. 15	92.6	0	.....	.....	.....	90.3	.....
19023–4	Milo, ground (with alfalfa) D. E. 132	Sheep No. 1	98.4	7.7	99.8	89.4	82.6	79.4	0
		Sheep No. 2	98.4	0.9	99.5	58.0	75.9	34.7	0
18772–3	Oats, rolled (with alfalfa) D. E. 125	Sheep No. 1	93.5	100.0	100.0	83.9	88.7	88.9	100.0
		Sheep No. 2	69.2	98.1	100.0	72.7	60.6	64.2	0
18867–8	Oats, rolled (with alfalfa) D. E. 126	Sheep No. 1	99.6	96.5	100.0	57.4	35.0	53.7	26.4
		Sheep No. 2	92.5	99.3	100.0	83.3	32.3	65.7	58.4
18748–9	Oat-hull clippings (with alfalfa) D. E. 124	Sheep No. 1	78.4	0	87.4	70.9	36.2	68.4	56.4
		Sheep No. 2	0	15.3	95.5	77.2	48.8	83.0	88.3
19833–4	Oat-hull clippings (with alfalfa) D. E. 137	Sheep No. 3	98.3	99.4	95.0	62.1	16.9	58.4	49.2
		Sheep No. 5	90.7	96.1	93.3	51.8	13.0	45.4	23.9
19125–6	Oat meal mill by-product (with alfalfa meal) D. E. 133	Sheep No. 1	92.6	98.4	99.4	38.3	32.6	34.1	15.5
		Sheep No. 2	97.2	78.7	100.0	50.0	30.8	46.9	32.4
19821–2	Oat meal mill by-product (with alfalfa meal) D. E. 136	Sheep No. 3	93.7	100.0	100.0	26.4	5.1	25.0	17.3
		Sheep No. 5	100.0	100.0	99.5	26.7	21.5	24.9	15.1
18932–3	Pinto beans (with alfalfa hay) D. E. 127	Sheep No. 1	85.7	100.0	99.0	94.2	87.8	92.2	69.2
		Sheep No. 2	100.0	99.1	98.8	86.4	83.6	78.6	0
23087–8	Rice bran (with alfalfa meal) D. E. 142	Sheep No. 3	94.3	100.0	100.0	52.3	33.9	43.7	1.5
		Sheep No. 5	95.5	100.0	99.6	52.6	41.4	44.3	3.2
20827–8	Rice polish (with alfalfa meal) D. E. 143	Sheep No. 13	100.0	95.2	100.0	93.7	50.6	81.9	0
		Sheep No. 15	100.0	99.1	100.0	100.0	76.5	88.1	0
23115–6	Rice polish (with alfalfa) D. E. 174	Sheep No. 3	98.8	100.0	100.0	99.3	78.1	92.8	40.4
		Sheep No. 15	100.0	99.0	100.0	77.8	60.6	72.1	35.0
18942–3–4–5	Velvet beans in pods (with alfalfa) D. E. 128	Sheep No. 1	99.2	97.5	95.3	100.0	96.5	100.0	100.0
		Sheep No. 2	96.1	98.8	97.5	94.1	84.5	89.9	73.3
24706	Wheat, whole (with alfalfa) D. E. 184	Sheep No. 3	95.4	100.0	98.1	92.8	90.3	89.7	71.7
		Sheep No. 15	100.0	100.0	99.6	98.7	99.3	100.0	100.0
23183	Wheat bran (with alfalfa) D. E. 177	Sheep No. 3	81.4	0	0	0	58.7	0	100.0
		Sheep No. 15	100.0	29.7	51.4	44.0	100.0	52.5	100.0
23159	Wheat gray shorts (with alfalfa) D. E. 175	Sheep No. 3	87.5	100.0	100.0	100.0	0	100.0	0
		Sheep No. 15	98.1	99.4	100.0	85.3	0	83.9	4.3
24383–4	Wheat Gray shorts (with alfalfa) D. E. 181	Sheep No. 3	100.0	98.2	100.0	75.7	82.1	74.8	79.2
		Sheep No. 15	100.0	98.4	100.0	80.8	78.4	83.0	100.0
18696–7	Wheat white shorts (with alfalfa) D. E. 123	Sheep No. 1	99.7	97.6	100.0	80.5	74.1	87.8	100.0
		Sheep No. 2	90.6	100.0	100.0	99.5	73.8	98.0	100.0
19018–19	Alfalfa meal		96.9	98.0	92.1	64.3	72.7	63.6	60.1
21948–9	Alfalfa D. E. 170		95.8	97.0	89.9	63.7	62.9	58.1	48.9
20715–16	Alfalfa meal		99.3	96.3	54.3	61.4	74.8	60.3	57.5
21824	Alfalfa meal		87.9	89.9	77.5	57.5	62.5	54.3	41.5
21948–9	Alfalfa D. E 154		97.0	98.0	93.5	64.9	71.1	59.8	49.2
19421–2	Alfalfa meal		97.3	98.5	100.0	55.7	69.3	53.1	47.7

NATURE OF THE RESIDUAL NITROGEN-FREE EXTRACT

The nitrogen-free extract of feeds is quite generally assumed to consist of sugars, starches, pentosans, and other carbohydrates. This assumption is not strictly correct. It is known that phytin (inosite phosphoric acid) may be present in cottonseed meal or wheat bran to the extent of 3 to 6 per cent and the organic part of phytin is part of the nitrogen-free extract. Chlorophyll, organic acids, and ligno-cellulose are also known to be present. Carbohydrates no doubt make up most of the nitrogen-free extract in concentrates such as corn, wheat, or milo. It is different, however, with roughages and by-products which consist partly of the woody or fibrous material of the plant. According to unpublished work of the writer, the nitrogen-free extract of these materials may contain large percentages of substances which it is not possible to hydrolize to sugars. The low digestibility of the residual nitrogen-free extract in some feeds is further evidence of its non-carbohydrate nature.

RELATION OF NITROGEN-FREE CONSTITUENTS TO FEEDING VALUE

It is known from the work of Kellner, Armsby, and others, that the value for energy purposes of the digested nutrients of roughages is much less than the value of concentrates. While a portion of this loss may be due to the work of chewing and digestion, a portion may also be due to the lower value of the chemical constituents of the hays and fodders, involving losses of energy both in digestion and in utilization of the digested nutrients. As has been pointed out in the preceding pages, the concentrates usually contain high percentages of starches, which can be readily digested and utilized. The roughages contain low percentages of starches, together with pentosans, and other carbohydrates, together with non-carbohydrate material, possibly, in relatively high percentages.

The low value of the digested material of roughages as compared with concentrates is thus associated with radical differences in chemical constituents. The nature of the constituents of the nitrogen-free extract of roughages offers a field for extensive study. Additional work will be reported by the Texas Agricultural Experiment Station.

SUMMARY

The percentages of sugars, starches, pentosans, and residual nitrogen-free extract were determined in a number of feeds.

The digestibility, by sheep, of the sugars, starches, pentosans,

and residual nitrogen-free extract, was determined on a number of feeds and average figures given for 56 feeds.

Feeds known to be of high feeding value are characterized by a high content of starch, or sugar and starch combined, or, if the starch content is not high, by a high content of protein.

The nitrogen-free extract of feeds of low feeding value contains high percentages of pentosans and of residual nitrogen-free extract.

The nitrogen-free extract of some feeds contains appreciable percentages of compounds which are not carbohydrates.

Sugars and starches have a high digestibility.

The digestibility of pentosans varies according to the kind of feed, being around 50 to 60 per cent with a number of feeds.

The pentosans in crude fiber are usually digested to a less extent than the total pentosans, or the pentosans in the nitrogen-free extract.

The residual nitrogen-free extract in hays and fodders is generally digested to a greater extent than are the pentosans.

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