On The Disintegration of Rice Straw

Iwata, Hisayoshi
Laboratory of Animal Nutrition, Department of Agriculture, Kyushu Imperial University

https://doi.org/10.5109/22329

出版情報：九州大学大学院農学研究院紀要. 1 (6), pp.217-240, 1926-05. Kyushu Imperial University
バージョン：
権利関係：

Journal of the Department of Agriculture, Kyushu Imperial University, Vol. 1, No. 6
May 25, 1926

ON THE DISINTEGRATION OF RICE STRAW

Hisayoshi IWATA

1. INTRODUCTION

Japanese agriculture consists principally of cropping, and the rice plant is the most important and extensively cultivated throughout the country. On the other hand live stock farming is very poor compared with that of foreign countries, and the farmers of this country utilise their live stock chiefly for agricultural work and for obtaining farm yard manure.

In winter they feed their farm animals mainly on rice straw mixed with rice bran and various other byproduct-fodders. In summer they use grass growing on uncultivated lands and dykes and ditches of paddy land, together with rice straw. Also they use a small amount of soy bean, barley, etc. as concentrated fodder for the draught animals.

Rice straw is therefore the most important and essential coarse fodder, especially in view of the fact that we have scarcely any meadow or pasture land in this country. The straw is generally simply chopped up and given to the cattle, but in some districts of Japan and also of Corea the chopped straw is boiled with water for several hours before being fed to the cattle. However this is doubly uneconomical; for boiling the fodder reduces its food value (13) while it requires a considerable amount of fuel. It seems therefore to be very important to settle the question of how the boiling of the straw affects its nutritive value.

It is also desirable to study some method such as straw-disintegration for improving the food value of the straw, in order to produce an abundant supply of good coarse fodder. In Germany since 1894 numerous investigations in regard to straw disintegration (7) have been carried out, and during the great war many sorts of straw were disintegrated on a large scale. The experiments however were made with rye, barley, oat straw etc. and work with rice straw has never before been attempted (3). Hence the author has studied not only the effect of boiling it with water, but also the action of various dilute alkaline solutions on the composition and nutritive value of the straw.

2. THE EFFECT OF VARIOUS TREATMENTS ON THE INCRUSTING SUBSTANCES OF RICE STRAW

It is known that the disintegration of the straw is due to the dissolution of incrusting substances and perhaps to the forcing or springing of the bonds uniting them to the other constituents. Accordingly the effect of various treatments on the incrusting substances was examined.

The straw used was harvested from the neighbourhood of the Kyushu Imperial University in 1923. Every 150 g. of straw, chopped into 2—3 cm. length, was treated with water, or with solutions of sodium hydroxide, sodium carbonate, calcium hydroxide, either by the cold or hot process, as shown in table II.

The cold process (at 22-25°C) employed was as follows. The sample was put into a large beaker, and soaked in various solutions for 4, 6, 8, or 24 hours. The amount of liquid in each case was equivalent in weight to eight times that of the straw. In the case of the hot process every 150 g. of the straw was put into a large flask, and 1200 c.c. of water or of one of the solutions NaOH, Na_2CO_3, $Ca(OH)_2$, of a definite concentration, was poured into it. These mixtures were boiled under a reflux condenser, part for 1.5 and part for 4 hours. After being thus treated, the alkaline liquor was filtered through linen, and the straw was thoroughly washed with water until the wash water no longer showed an alkaline reaction, and was then dried in the air.

This disintegrated straw had a clear yellowish green colour as long as it showed an alkaline reaction; but when neutral it became

dark brown. The brittleness of the disintegrated straw gradually increased as the degree of disintegration proceeded.

Each of the samples thus obtained was submitted to tests for the determination of ash, silica, lignin and the chlorine number.

Proceeding the determination of lignin (8), the author compared the WILLSTÄTTER's method which uses 42% HCl (16), with the OST and WILKENING's method which uses 72% H_2SO_4 (10 and 11). MAGNUS (9) employed the former method in his investigation, and ARCHIBALD employed the latter, after modifying it himself (1). He diluted the hydrolysed solution with ordinary tap water to a strength of 3% of sulfuric acid and filtered with linen and a gooch crucible, but the author diluted with distilled water and filtered with ordinary filter paper.

With five sorts of disintegrated straw the following results were obtained.

Table I. Comparison of WILLSTÄTTER's method with OST-WILKENING's method.

No. of sample	WILLSTÄTTER-Lignin	OST-WILKENING-Lignin	Ratio $= \frac{\text{W-Lignin}}{\text{O-Lignin}}$
1	12.55	13.45	0.933
2	12.41	13.09	0.948
3	12.27	13.08	0.938
4	11.67	12.26	0.952
5	10.01	10.49	0.954
Average			0.945

From this table it is seen that the results of these two methods coincide well with each other, deviating only by 5 per cent. Therefore the author employed the simpler and easier method namely OST-WILKENING's.

The chlorine number was measured by a modification of the method of WAENTIG and CIERISCH (14 and 15), the principle of which consists in the combination of chlorine with lignin. The method in brief was as follows: 10 g. of coarsely milled straw was put into a chlorine absorption cylinder and moistened with 20 c.c. of 1% hydrochloric acid solution. The chlorine gas, saturated with water vapor, was passed through the straw for 30 minutes, then air was passed through for 15 minutes in order to expel the excess of chlorine gas remaining in the absorption cylinder, and then the amount of chlorine absorbed was measured. The amount of maximum absorption in percentage gave the chlorine number.

Table II. The incrusting substances of the treated straw

Treatments				Incrusting substances %				Yield %	Loss %		
Reagent	Concentration	Temperature	Hours	Ash	Silica	Lignin	Cl-number		Ash	Silica	Lignin
Untreated straw				20.13	17.52	14.69	19.4	100.00	—	—	—
Water	—	22-25°C	4	19.60	17.45	14.36	18.4	90.81	2.33	1.67	1.65
,,	—	Boiling P.	,,	18.46	16.72	14.35	18.1	85.92	4.27	3.15	2.36
NaOH	0.25	22-25°	4	15.33	13.48	14.47	18.4	85.63	7.01	5.98	2.30
,,	0.50	,,	,,	15.56	13.47	14.34	18.0	83.33	7.16	6.30	2.74
,,	1.00	,,	,,	11.44	9.39	13.48	16.2	75.73	11.46	10.40	4.47
,,	1.50	,,	,,	10.13	8.31	12.29	14.4	71.86	12.85	11.55	5.86
,,	2.00	,,	,,	10.22	8.19	11.52	12.7	69.12	13.07	11.86	6.73
NaOH	0.50	22-25°	8	15.86	13.97	14.19	17.0	82.22	7.07	6.03	3.02
,,	1.00	,,	,,	10.36	8.50	13.33	15.8	73.27	12.54	11.29	4.92
,,	1.50	,,	,,	9.20	7.09	11.95	13.5	69.72	13.72	12.58	6.36
,,	2.00	,,	,,	10.56	7.66	11.12	12.2	67.20	12.97	12.37	7.22
NaOH	0.50	22-25°	24	16.49	13.91	13.74	16.7	82.67	6.50	6.02	3.33
,,	1.00	,,	,,	9.03	6.75	13.38	15.7	71.42	13.63	12.70	5.13
,,	1.50	,,	,,	6.04	3.92	11.09	13.7	65.13	16.20	14.97	7.47
NaOH	0.50	Boiling P.	4	18.51	16.46	9.74	10.0	70.31	7.12	5.95	7.84
,,	0.50	,,	1.5	17.78	15.65	11.68	13.6	78.52	6.17	5.23	5.52
,,	1.00	,,	,,	12.46	10.95	9.19	10.2	66.76	11.81	10.21	8.55
Na_2CO_3	0.66	22-25°	6	17.94	16.58	14.33	19.3	85.26	4.83	3.38	2.47
,,	1.33	,,	,,	18.31	15.40	14.34	19.3	85.48	4.48	4.36	2.43
,,	1.99	,,	,,	18.44	14.44	14.41	19.1	83.41	4.75	5.48	2.67
Na_2CO_3	0.66	Boiling P.	1.5	18.17	15.92	12.50	14.5	77.19	6.10	5.23	5.04
,,	1.33	,,	,,	17.81	15.67	11.16	13.1	73.79	6.99	5.96	6.46
,,	1.99	,,	,,	17.30	15.20	10.18	12.1	70.31	7.97	6.83	7.53
CaO	1.00	22-25°	24	20.34	13.49	—	—	84.37	2.97	6.14	—
,,	1.25	,,	,,	20.07	15.67	12.63	15.3	83.56	3.36	4.43	4.14
,,	1.00	Boiling P.	4	22.38	14.95	12.06	15.0	81.00	2.00	5.41	4.92
,,	1.25	,,	,,	25.01	16.13	12.09	15.1	76.52	0.99	5.18	5.44

WAENTIG reports that the chlorine number corresponds nearly to 150% of the amount of WILLSTÄTER-Lignin, but according to this experiment it was found by measurement to be 120-140% of the WILLSTÄTTER-Lignin, and 110-130% of OST-WILKENING-Lignin. However, the amount of lignin and the chlorine number were nearly proportional to each other.

The results of analysis together with the decrease of the incrusting substances during the disintegration process are shown in table II, in dry matter percentages.

When the straw was only immersed in distilled water for 4 hours, a slightly dilute dark brown extract was obtained, but no appreciable decrease in the amount of the incrusting substances or of the chlorine number was observed.

When it was boiled with distilled water for 4 hours, there was almost no change compared with the former process, except that the contents of ash and silica were slightly decreased which may be due to the loss of sand adhering to the straw.

When treated with solutions of sodium hydroxide either by the cold or hot process, the influence of concentration on the degree of disintegration was very remarkable In the case of the cold process such dilute solutions as 0.25 or 0.5% of sodium hydroxide did not affect the amount of silica and lignin or the chlorine number; however the disintegration increased suddenly when the concentration became higher than 1% of sodium hydroxide, but was not proportional to the concentration. The analysis of the results of disintegration with cold sodium hydroxide solution indicates that the content of silica was always less than that of lignin, while all the other disintegrated straw showed the reverse. The maximum extraction of silica was already reached when treated with the 1.5% caustic soda solution for 4 or 8 hours; actually more than half of the total silica contained in the straw was removed. As regards the extraction of lignin it differed somewhat from that of silica, in that it was not noticeably promoted, even when the concentration of the reagent was increased as high as 1.5 or 2% sodium hydroxide; also its loss in percentage was so small that it did not reach half of that of the silica.

When boiled with 0.5% or 1% caustic soda solution, part for 1.5, part for 4 hours, the loss of silica was smaller than when treated by the cold process, on the contrary the lignin and chlorine number decreased very remarkably compared with the cold process.

When immersed for 6 hours in one of the following cold sodium carbonate solutions 0.66, 1.33 and 1.99% of Na_2CO_3, equivalent respectively to 0.5, 1.0 and 1.5% of NaOH, in every case there was no remarkable effect on the content of lignin and the chlorine number, but the amount of silica slightly decreased. On the other hand when boiled with the same sodium carbonate solution as above for 1.5 hours, the dissolution of lignin was much accerelated, while scarcely any silica was eliminated.

When treated with calcium hydroxide, only slight losses of ash and silica were observed and sometimes the content of ash showed a little increase, because the calcium hydroxide could not be thoroughly washed out. But the content of lignin and the chlorine number considerably decreased, and their numerical value approximated to that of the straw which was treated with sodium hydroxide solution (1.0 or 1.5% NaOH) at ordinary temperature.

From the above facts, the following statements can be made.

1) It was hardly possible to disintegrate the rice straw with cold or boiling water or with solution of 0.25, 0.5% sodium hydroxide and 0.66, 1.33, 1.99% sodium carbonate, at ordinary temperature.
2) When treated with solutions that contain more than 1% of sodium hydroxide, the amount of both lignin and silica were considerably decreased.
3) When disintegrated with boiling milk of lime (1.0 or 1.25% CaO) a considerable portion of the lignin was removed, but the silica was scarcely touched.
4) When boiled with the solution of sodium hydroxide and sodium carbonate, a noticeable quantity of lignin was extracted, compared with the cold process.
5) As regards the influence of the time of treatment with cold sodium hydroxide solutions upon the dissolution of the incrusting substances, the greatest amount of dissolution took place in the first four hours (2 and 5).

3. THE EFFECT OF THE TREATMENT ON THE COMPOSITION AND NUTRITIVE VALUE OF THE RICE STRAW

The quantitative effect of several treatments on the incrusting substances of straw having been studied, the author now tried to find out the effect of these treatment on the nutritive value.

The samples were prepared as follows.

1) Untreated rice straw :—The same as that employed for the previous experiments.

2) Boiled straw :—Every 2 kilos of chopped straw were boiled with 16 liters of water, keeping up the amount of water by supplying hot water, for 3 hours with frequent stirring. The brown liquor was then drained off. The straw was washed with water and then dried at 50-60°C. This boiled straw became dark brown and fragrant. Rams and cattle rather prefered the wet boiled straw to the dry.

3) Soda straw I :—Every 6 kilos of the chopped straw was put into a large pot, about 60 liters capacity, provided with an outlet tap at the bottom to drain off the lye and wash water. Then 48 liters of 0.75 % caustic soda solution, weighing 8 times as much as the straw were added, and thoroughly stirred. The mixture was allowed to stand for 3 hours, under the pressure of a weight stone, at ordinary temperature 20°C. The alkaline dark brown liquor was completely drained off and the straw was thoroughly washed until the wash water showed a neutral reaction, and then dried in the air. This soda straw I. had a dark brown colour and fragrant odour; its original form was not changed but it became somewhat brittle. Rams and cattle ate it readily either wet or dry.[1]

4) Soda straw II :—Treated with 1.5% caustic soda solution at ordinary temperature 20°C. with the same procedure as above. This preparation had the same appearence as the straw I., and was eaten readily by rams and cattle.

5) Soda straw III. :—Treated with 0.25% caustic soda solution at 8°C. by the same procedure as above, and dried at 50-60°C. This preparation was dark brown and as hard as the original straw. The rams and cattle showed as little relish for it as for the untreated straw either in the wet or dry state.

6) Lime straw :—Every 2 kilos of chopped straw was boiled with 16 liters of water and 160 g. of calcium hydroxide for 3 hours with frequent stirring. It was then washed with water until the wash water became colourless. This air dried lime straw lost the lustre

[1] Afterwards the straw, thus treated and containing about 80% of moisture was fed to a cow and a horse at the Imperial College of Agricultre and Forestry in Morioka, and they ate 10-15 kilos of it per day, mixed with concentrated fodder.

of the original straw, and became fragrant and brittle. Rams and cattle liked it and ate it readily in either the wet or dried form.[2)]

Proceeding the determination of the nutritive value, these six preparation were analysed in the usual way, crude fiber being determined by the WEENDE process, and the protein by STUTZER-BARNSTEIN's method. The results of analysis are shown in table VII.

In order to investigate the nutritive value, the digestion coefficients were estimated according to the ordinary method. Two rams were kept in the feeding box and fed on a definite ration of fodder. After the preliminary period of 5-8 days, the main period was continued for 10 days. The faeces were collected during the main period every day, and 1/10 of its amount was dried at 55-60°C, and then submitted to the usual analysis. Since both the untreated and treated straws were very poor in protein, Genge hay (Astragalus sinicus L.) which was made at the Farm of the University in June 1924, was given together with the sample, mixed with 10 g. of common salt. All of these fodders were completely consumed by the rams in every case. In the first feeding experiment the digetion coefficients of Genge hay were ascertained, and then those of the other six sample fodders were determined one after another.

The rations of each period and the dry matter contents of each fodder are shown in the next table.

Table III. The rations of each period

Period	Fodder	Dry matter %	Weight g.	
			Ram No. I.	Ram No. II.
1	Genge hay	86.38	700	700
2	Genge hay	84.81	350	350
	Untreated straw	87.99	250	250
3	Genge hay	86.38	350	350
	Soda straw I.	90.61	250	250
4	Genge hay	88.66	350	350
	Soda straw II.	90.33	300	300

2) Afterwards the lime straw, thus disintegrated and containing about 82% of moisture, was mixed with concentrated fodder, and fed to live stock for 70 days at the Imperial College of Agriculture and Forestry in Morioka. 15 kilos of it was eaten daily by a horse, 11 kilos by a cow, and 4 kilos by a pig, with good result in regard to their body weight and milk production.

Table III. (Continued).

Period	Fodder	Dry matter %	Weight g.	
			Ram No. I.	Ram No. II.
5	Genge hay	88.66	350	350
	Lime straw	91.23	300	300
6	Genge hay	91.19	350	350
	Boiled straw	91.73	250	200
7	Genge hay	91.19	350	350
	Soda straw III.	93.17	250	250

The daily excretion of faeces during each main period is as shown in the appendix, and the average quantity of dry matter per head per day is shown in the next table.

Table IV. Excretion in grams of the dry matter of the faeces.

Period	Fodder	Ram I	Ram II
1	Genge hay	254.8	247.1
2	Untreated straw	258.4	243.1
3	Soda straw I. (0.75% NaOH)	213.3	208.5
4	Soda straw II. (1.5% NaOH)	234.1	228.5
5	Lime straw (1.% CaO)	249.7	259.9
6	Boiled straw	261.4	235.6
7	Soda straw III. (0.25% NaOH)	275.8	272.1

The digestibility of nutrients of Genge hay was calculated as follows, according to the data of table III, IV, and V (a).

Table V.

1st period :—Genge hay

a) Composition of dried substances.

	Genge hay	Faeces	
		Ram No. I.	Ram No. II.
	%	%	%
Organic matter	92.93	88.81	88.07
Crude protein	21.08	16.12	15.65
Nitrogen free extract.	38.11	28.22	29.35
Crude fat	3.32	2.59	2.61
Crude fiber	30.42	41.88	40.46
Protein	19.56		

b) Calculation of digestion coefficients.

Ram No. I. Live weight 41.0—40.1 K.

	Dry matter g.	Organic matter g	Crude protein g.	N. free extract g.	Crude fat g.	Crude fiber g.
Genge hay 700 g.	604.7	561.9	127.5	230.5	20.1	183.9
Faeces excreted	254.8	226.3	41.1	71.9	6.6	106.7
Digested	349.9	335.6	86.4	158.6	13.5	77.2
Digestion coefficients. . . .	57.86	59.73	67.76	68.81	67.16	41.98

Ram No. II. Live weight 42.0—42.0 K.

Genge hay 700 g.	604.7	561.9	127.5	230.5	20.1	183.9
Faeces excreted	247.1	217.6	38.7	72.5	6.4	100.0
Digested	357.6	344.3	88.8	158.0	13.7	83.9
Digestion coefficients . . .	59.14	61.27	69.65	68.55	68.16	45.62
Average digestion coeff. . .	58.5	60.5	68.7	68.7	67.7	43.8

From these results it is seen, that the Genge hay contains about 13 % of digestible protein, and its starch value is 38.3 %. This hay therefore can be considered to be one of the very good coarse fodders in this country.

Next, with the help of the data shown in tables III, IV and VI (a), and the figures obtained as to the composition and digestibility of the Genge hay, the digestibility of the untreated straw and the other treated straws were calculated as follows.

Table VI

2nd period :—Untreated straw.

a) Composition of dried substances.

	Untreated straw	Faeces	
		Ram No. I.	Ram No. II.
	%	%	%
Organic matter	79.87	77.95	77.28
Crude protein	6.15	10.89	10.91
Nitrogen free extract	36.61	31.81	32.14
Crude fat	1.89	2.41	2.36
Crude fiber	35.22	32.84	31.87
Protein	5.84		

b) Calculation of digestion coefficients.

Ram No. I. Live weight 40.05 – 39.0 K.

	Dry matter g.	Organic matter g.	Crude protein g.	N. free extract g.	Crude fat g.	Crude fiber g.
Genge hay 350 g.	296.8	275.6	62.6	113.1	9.9	90.3
Untreated straw 250 g	220.0	175.7	13.5	80.5	4.2	77.5
Amount consumed.	516.8	451.5	76.1	193.6	14.1	167.8
Faeces excreted	258.4	201.4	28.1	32.2	6.2	84.9
Amount digested	258.4	250.1	48.0	111.4	7.9	82.9
Digested from hay	171.7	164.7	42.4	77.8	6.6	37.9
Digested from straw	86.7	85.4	5.6	33.6	1.3	45.0
Digestion coefficients	39.41	48.61	41.48	41.47	30.95	58.06

Ram No. II. Live weight 43.0 – 41.3 K.

Amount consumed (same to No I.)	516.8	451.5	76.1	193.6	14.1	167.8
Faeces excreted	243.1	187.9	26.5	78.1	5.7	77.5
Amount digested	273.7	263.6	49.6	115.5	8.4	90.3
Digested from hay	175.5	169.0	43.6	77.5	6.7	41.2
Digested from straw	98.2	94.6	6.0	38.0	1.7	49.1
Average digestion coeff.	42.0	51.2	43.0	44.5	35.7	60.7

3rd period :—Soda straw I. (0.75 % NaOH).

a) Composition of dried substances.

	Soda straw I.	Faeces	
		Ram No. I.	Ram No. II.
	%	%	%
Organic matter	86.35	78.39	78.23
Crude protein	5.75	14.25	14.32
Nitrogen free extract	38.62	30.45	30.27
Crude fat	1.64	2.85	3.01
Crude fiber	40.34	30.84	30.63
Protein	4.71		

b) Calculation of digestion coefficients.

Ram No. I. Live weight 39.4—39.7 K.

	Dry matter g.	Organic matter g.	Crude protein g.	N. free extract g.	Crude fat g.	Crude fiber g
Genge hay 350 g.	302.3	280.9	63.7	115.2	10.0	92.0
Soda straw I. 250 g.	226.5	195.6	13.0	87.5	3.7	91.4
Amount consumed	528.8	476.5	76.7	202.7	13.7	183.4
Faeces excreted	213.3	167.2	30.4	64.9	6.1	65.8
Amount digested	315.5	309.3	46.3	137.8	7.6	117.6
Digested from hay . . .	174.9	167.8	43.2	79.3	6.7	38.6
Digested from soda straw I. .	140.6	141.5	3.1	58.5	0.9	79.0
Digestion coefficients . . .	62.08	72.34	23.85	66.86	24.32	86.43

Ram No. II. Live weight 41.—41.4 K.

Amount consumed (same to No. I.) .	528.8	476.5	76.7	202.7	13.7	183.4
Faeces excreted	208.5	163.1	29.9	63.1	6.3	63.9
Amount digested	320.3	313.4	46.8	139.6	7.4	119.5
Digested from hay	178.8	172.1	44.4	79.0	6.8	42.0
Digested from soda straw I. .	141.5	141.3	2.4	60.6	0.6	77.5
Digestion coefficients. . . .	62.47	72.24	18.46	69.26	16.22	84.79
Average digestion coeff . . .	62.3	72.3	21.2	68.1	20.3	85.6

4th period:—Soda straw II. (1.5 % NaOH).

a) Composition of dried substances.

	Soda straw II.	Faeces	
		Ram No. I.	Ram No. II.
	%	%	%
Organic mattter	86.12	78.16	76.27
Crude protein	5.68	14.70	14.52
Nitrogen free extract	35.83	29.27	28.45
Crude fat	1.70	2.97	2.99
Crude fiber	42.91	31.22	30.31
Protein	4.80		

b) Calculation of digestion coefficients.

Ram No. I. Live weight 39.6—38.9 K.

	Dry matter g.	Organic matter g.	Crude protein g	N. free extract g.	Crude fat g.	Crude fiber g.
Genge hay 350 g.	310.3	288.4	65.4	118.3	10.3	94.4
Soda straw II. 300 g.	271.0	233.4	15.4	97.1	4.6	116.3
Amount consumed	581.3	521.8	80.8	215.4	14.9	210.7
Faeces excreted	234.1	183.0	34.4	68.5	7.0	73.1
Amount digested	347.2	338.8	46.4	146.9	7.9	137.6
Digested from hay	179.5	172.3	44.3	81.4	6.9	39.6
Digested from soda straw II. .	167.7	166.5	2.1	65.5	1.0	98.0
Digestion coefficients. . . .	61.88	71.34	13.64	67.46	21.74	84.26

Ram No. II. Live weight 40.8—41.2 K.

Amount consumed (same to No. I) .	581.3	521.8	80.8	215.4	14.9	210.7
Faeces excreted	228.5	174.3	33.2	65.0	6.8	69.3
Amount digested	352.8	347.5	47.6	150.4	8.1	141.4
Digested from hay	183.5	176.7	45.6	81.1	7.0	43.1
Digested from soda straw II. .	169.3	170.8	2.0	69.3	1.1	98.3
Digestion coefficients. . . .	62.47	73.18	12.99	71.37	23.91	84.52
Average digestion coeff. . . .	62.2	72.3	13.3	69.4	22.8	84.4

5th period :—Lime straw.

a) Composition of dried substances.

	Lime straw.	Faeces	
		Ram No. I.	Ram No. II.
	%	%	%
Organic matter.	79.02	70.72	70.36
Crude protein	4.75	14.45	13.43
Nitrogen free extract.	28.97	26.24	26.62
Crude fat	1.84	2.77	2.73
Crude fiber	43.46	27.26	27.58
Protein	4.17		

b) Calculation of digestion coefficients.

Ram No. I. Live weight 39.2—39.5 K.

	Dry matter g.	Organic matter g.	Crude protein g.	N. free extract g.	Crude fat g.	Crude fiber g.
Gonge hay 350 g.	310.3	288.4	65.4	118.3	10.3	94.4
Lime straw 300 g.	273.7	216.3	14.0	79.3	5.0	119.0
Amount consumed.	584.0	504.7	78.4	197.6	15.3	213.4
Faeces excreted	249.7	176.6	36.1	65.5	6.9	68.1
Amount digested	334.3	328.1	42.3	132.1	8.4	145.3
Digested from hay	179.5	172.3	44.3	81.4	6.9	39.6
Digested from lime straw	154.8	155.8	—	50.7	1.5	105.7
Digested coefficients	56.56	72.03	—	63.93	30.00	88.82

Ram No. II. Live weight 40.0—39.6 K.

Amount consumed (same to No. I.)	584.0	504.7	78.4	197.6	15.3	213.4
Faeces excreted	259.9	182.9	34.9	69.2	7.1	71.7
Amount digested	324.1	321.8	43.5	128.4	8.2	141.7
Digested from hay	183.5	176.7	45.6	81.1	7.0	43.1
Digested from lime straw	140.6	145.1	—	47.3	1.2	98.6
Digestion coefficients.	51.37	67.08	—	59.65	24.00	82.86
Average digestion coeff.	54.0	69.6	—	61.8	27.0	85.8

6th period :—Boiled straw.

a) Composition of dried substances.

	Boiled straw	Faeces	
		Ram No. I.	Ram No. II.
	%	%	%
Organic matter.	80.97	78.00	79.27
Crude protein	5.97	11.28	11.87
Nitrogen free extract.	36.72	31.58	31.50
Crude fat	1.75	2.15	2.17
Crude fiber	36.53	32.99	33.73
Protein	4.86		

b) Calculation of digestion coefficients.

Ram No. I. Live weight 40.2—40.0 K.

	Dry matter g.	Organic matter g.	Crude protein g.	N. free extract g.	Crude fat g.	Crude fiber g.
Genge hay 350 g.	319.2	296.6	67.3	121.6	10.6	97.1
Boiled straw 250 g.	229.3	185.7	13.7	84.2	4.0	83.8
Amount consumed.	548.5	482. 3	81.0	205.8	14.6	180.9
Faeces excreted	261.4	203.9	29.5	82.6	5.6	86.2
Amount digested	287.1	278.4	51.5	123.2	9.0	94.7
Digested from hay	184.7	177.2	45.6	83.7	7.1	40.8
Digested from boiled straw	102.4	101.2	5.9	39.5	1.9	53.9
Digestion coefficients.	44.66	54.50	43.07	46.91	47.50	64.32

Ram No. II. Live weight 38.5—39.1 K.

Genge hay 350 g.	319.2	296.6	67.3	121.6	10.6	97.1
Boiled straw 250 g.	183.5	148.6	11.0	67.4	3.2	67.0
Amount consumed.	502.7	445.2	78.3	189.0	13.8	164.1
Faeces excreted	235.6	186.8	28.0	74.2	5.1	79.5
Amount digested	267.1	258.4	50.3	114.8	8.7	84.6
Digested from hay	188.8	181.7	46.9	83.4	7.2	44.3
Digested from boiled straw.	78.3	76.7	3.4	31.4	1.5	40.3
Digestion coefficients.	42.67	51.61	30.91	46.58	46.87	60.14
Average digestion coeff.	43.7	53.1	37.0	46.7	47.2	62.2

7th period:—Soda straw III. (0.25 % NaOH).

a) Composition of dried substances.

	Soda straw III.	Faeces	
		Ram No. I.	Ram No. II.
	%	%	%
Organic matter	80.39	77.98	77.91
Crude protein	6.06	11.56	11.48
Nitrogen free extract	35.73	32.20	32.71
Crude fat	1.61	1.94	2.03
Crude fiber	36.99	32.28	31.69
Protein	5.21		

b) Calculation of digestion coefficients.

Ram No. I. Live weight 40.0—39.4 K.

	Dry matter g.	Organic matter g.	Crude protein g.	N. free extract g.	Crude fat g.	Crude fiber g.
Genge hay 350 g.	319.2	296.6	67.3	121.6	10.6	97.1
Soda straw III. 250 g. . . .	232.9	187.2	14.1	83.2	3.7	86.1
Amount consumed	552.1	483.8	81.4	204.8	14.3	183.2
Faeces excreted	275.8	215.1	31.9	88.8	5.4	89.0
Amount digested	276.3	268.7	49.5	116.0	8.9	94.2
Digested from hay	184.7	177.2	45.6	83.7	7.1	40.8
Digested from Soda straw III.	91.6	91.5	3.9	32.3	1.8	53.4
Digestion coefficients. . . .	39.33	48.88	27.66	38.82	48.65	62.02

Ram No. II. Live weight 40.4—39.0 K.

Amount consumed (same to No. I.) .	552.1	483.8	81.4	204.8	14.3	183.2
Faeces excreted	272.1	212.0	31.2	89.0	5.2	86.2
Amount digested	280.0	271.8	50.2	115.8	9.1	97.0
Digested from hay	188.8	181.7	46.9	83.4	7.2	44.3
Digested from soda straw III. .	91.2	90.1	3.3	32.4	1.9	52.7
Digestion coefficients. . . .	39.16	48.13	23.40	38.94	51.35	61.21
Average digestion coeff. . . .	39.2	48.5	25.3	38.9	50.0	61.6

In accordance with these data, the amount of digestible nutrients of the six sample fodders were calculated; also the starch value by KELLNER's method for untreated straw, boiled straw and soda straw III. The same method was used to calculate the starch value in the case of the two latter because they were quite similar to the untreated straw in respect of the contents of digestible matters; however in the case of intensely disintegrated straw, such as soda straw I., II. and lime straw, FINGERLING's method (4) was used.

The results of this experiment coincided very well with those of the previous one (compare tables II and VII). They show that whilst scarcely any lignin or silica could be extracted by the 0.25 % NaOH solution, 0.75 % or 1.5 % solution extracted a certain quantity of both; and the boiling milk of lime (1% CaO) extracted the same quantity of lignin as above but no silica. The effect of caustic soda on the rice straw was almost the same as on other kinds of straw reports of which

Table VII. Composition and nutritive value of untreated straw, boiled straw and disintegrated straw

		In 100 parts of dry matter (%)						Loss or gain due to treatments (%)				
		Untreated straw	Boiled straw	Soda straw III. (0.25%NaOH)	Soda straw I (0.75%NaOH)	Soda straw II. (1.5%NaOH)	Lime straw (1% CaO)	Boiled straw	Soda straw III.	Soda straw I.	Soda straw II.	Lime straw
	Yield	100.00	88.32	94.87	76.58	79.68	84.16	−11.68	−5.13	−23.42	−20.32	−15.84
Composition	Organic matter	79.87	80.97	80.39	86.35	86.12	79.02	−3.36	−3.60	−13.74	−11.25	−13.37
	Crude protein	6.15	5.97	6.06	5.75	5.68	4.75	−0.88	−0.49	−1.75	−1.62	−2.15
	Nitrogen free extract	36.61	36.72	35.73	38.62	35.83	28.97	−4.18	−2.69	−7.03	−3.06	−12.23
	Crude fat	1.89	1.75	1.61	1.64	1.70	1.84	−0.34	−0.36	−0.63	−0.54	−0.34
	Crude fiber	35.22	36.53	36.99	40.34	42.91	43.46	−2.96	−0.13	−4.33	−1.03	−1.36
	Crude ash	20.13	19.03	19.61	13.65	13.88	20.98	−3.32	−1.53	−9.68	−9.08	−2.47
	Silica	17.52	17.30	17.25	11.75	11.69	15.26	−2.24	−1.15	−8.52	−8.23	−4.68
	Pentosan	21.32	22.38	22.45	24.23	24.82	22.39	−1.55	−1.47	−2.76	−1.54	−2.48
	Lignin	14.69	14.14	14.60	13.20	12.66	12.12	−2.20	−0.84	−4.58	−4.63	−4.49
	Chlorine number	19.4	17.0	18.5	16.4	15.8	13.5	—	—	—	—	—
Digestible nutrients	Organic matter	40.89	43.00	38.99	62.43	62.26	55.00	−2.91	−3.90	+6.92	+6.72	+5.40
	Crude protein	2.64	2.21	1.55	1.22	0.76	—	−0.69	−1.17	−1.71	−2.03	−2.64
	Nitrogen free extract	16.29	17.15	13.90	26.30	24.87	17.90	−1.14	−3.10	+3.85	+3.53	+1.23
	Crude fat	0.67	0.83	0.81	0.33	0.39	0.50	+0.06	+0.10	−0.42	−0.36	−0.25
	Crude fiber	21.38	22.72	22.79	34.53	36.22	37.29	−1.31	+0.24	+5.06	+7.48	+10.00
	Protein	2.33	1.11	0.70	0.18	—	—	−1.35	−1.67	−2.19	—	—
	Starch value	20.71	21.30	17.45	58.26	57.95	52.57	−2.90	−4.16	+23.91	+25.41	+24.53

have been made by many investigators. But as regards the lime disintegration, BECKMANN (2), HONCAMP (6) and MAGNUS (9) think the lignin combines with calcium to form a hard soluble compound which prevents further disintegration of the straw. However the author's experiments with rice straw do not suggest such a conclusion. The content of pentosan rather increased in the case of rice straw, which is the opposite of the results obtained in the case of other sorts of straw (9); at the same time there was a total loss of pentosan of only 1.5—2.5 %.

The content of fiber remarkably increased by the treatment with 0.75 or 1.5 % sodium hydroxide and boiling milk of lime; that is to say about 40 % of crude fiber was contained in the soda straw I, II, and lime straw, whilst there was about 35 % in the untreated, straw and also in the boiled straw and in the soda straw III. The content of nitrogen free extract was hardly changed, except in the case of lime disintegration. Both fat and protein decreased a good deal, but the absolute losses were negligible.

The digestibility of the total organic matter, of crude fiber and of nitrogen free extract was remarkably promoted by the treatment either with 0.75 or 1.5 % sodium hydroxide cold solution. The lime disintegration increased the contents of digestible organic matter and crude fiber to the same extent as with the cold caustic soda solution; but that of the digestible nitrogen free extract was only slightly increased. The amount of digestible fat and protein decreased in every case, but the absolute amount of losses was negligible.

The starch value of the untreated straw was 20 %, which agree very well with the results of the wide researches of Prof. T. KATAYAMA and Mr. GOTO (not yet reported).

Comparing the nutritive values of these six sample fodders, the starch value of soda straw I, II, and lime straw was more than 50 %, nearly three times that of the untreated straw. Even when these was some loss of nutrients by the treatments, the starch value increased to about 2.5 times that of the untreated straw. The treatments with 0.25 % sodium hydroxide solution and boiling water however had no noticeable effect on the starch value.

As it is obvious from the above statements, the boiling of the straw exerts no effect on its nutritive value. However it must be admitted that the cattle can eat a larger amount of boiled straw owing to its good taste and flavour; moreover in winter it can supply a

certain amount of heat energy to the animal body. In the case of boiling, however, it is rather advisable to use 8 parts of lime for 100 parts of straw, since the starch value can be easily doubled and also the taste improved.

The relation between the nutritive value and the quantity of incrusting substances can be explained from the above results as follows. The boiled straw and soda straw III. contained a large quantity of lignin and silica, but its starch value was low, nearly equal to the untreated straw; the soda straw I. and II. contained considerably less lignin and silica, and was of high starch value; while the content of lignin in the lime straw approximated to that of soda straw I. and II, and that of silica approximated to that of the original straw, yet its starch value was nearly equal to that of soda straw I. and II.

Hence it may be concluded that the increase in the nutritive value produced by disintegration is to be mainly attributed to the removal of a certain amount of lignin, though the removal of the silica probably exerts no appreciable effect upon the nutritive value. Also it is seen that the increase of the starch value was not proportional to the decrease of the lignin content, hence that increase may be due not only to the decrease of lignin but also to the physical and chemical (12) changes in the incrusting substances.

4. SUMMARY

The author has investigated the effects of boiling with water and disintegration with alkaline solutions on the chemical composition and nutritive value of rice straw. The results are summarised as follows.

1) The starch value of the straw in dry matter was about 20 %, which agrees with the result of Prof. T. KATAYAMA's experiments.
2) The boiling for 3 hours in water did not change the chemical composition and nutritive value of the straw.
3) When the straw was soaked in 0.25 % sodium hydroxide solution for 4 hours, hardly any of its incrusting substances were removed, its digestibility was not promoted, and also the starch value, percent of dry matter, was nearly the same as that of the untreated straw.

   However when the straw was immersed 0.75 or 1.5 % sodium hydroxide solution for 4 hours, or when it was boiled with the milk of lime (1 % CaO) for 3 hours, a considerable quantity of

the incrusting substances were extracted, the amount of digestible matter was much increased, and also its starch value became as much as thrice that of the untreated straw; actually it contained 53–58 % of starch value in dry matter.

4) When the contents of the lignin and chlorine number decreased, the starch value of the treated straw increased, but not proportionally.

5) The data obtained in dry matter percentages were as follows:

	Uttreated straw	Boiled straw	Soda straw III. (0.25%NaOH)	Soda straw I. (0.75%NaOH)	Soda straw II. (1.5%NaOH)	Lime straw (1%CaO)
Content of digestible organic matter . .	40.89	43.00	38.99	62.43	62.26	55.00
Chlorine number . .	19.4	17.0	18.5	16.4	15.8	13.5
Content of lignin . .	14.69	14.14	14.60	13.20	12.66	12.12
Starch value . . .	20.71	21.30	17.45	58.26	57.95	52.57

In conclusion the author expresses his best thanks to Prof. Dr. T. KATAYAMA under whose guidance this investigation was made, and also Mr S. AIHARA and Mr. J. YASUNAGA for their valuable assistance during the feeding experiments.

Jan. 10, 1926. In the Laboratory of Animal Nutrition, Department of Agriculture, Kyushu Imperial University.

REFERENCES

1. ARCHIBALD: Jour. Agr. Research. **27,** 245, 1924.
2. BECKMANN: Sitzungsb. d. Preuss, Akad. d. Wissenschaft. **17,** 275, 1917.
3. BECKMANN: Biochem. Z. **139,** 491, 1923.
4. FINGERLING: Landw. Versuchsstat. **92,** 1, 1919.
5. FINGERLING und SCHMIDT: Landw. Versuchsstat. **94,** 115, 1919.
6. HONCAMP und BAUMANN: Landw. Versuchsstat. **98,** 1, 1921.
7. KELLNER: Die Ernährung d. landw. Nutztiere. 10. Aufl., 268, 1924.
8 KÖNIG: Untersuchung landwl. u. landw.- gewerbl. wicht. Stoffe. 5. Aufl., **I,** 396.
9. MAGNUS: Theorie u. Praxis d. Strohaufschliessung. 1919.
10. MAHOOD and CABLE: J. Ind. Eng. Chem. **14,** 727, 1922.
11. OST und WILKENING: Chem. Z. **34,** 461, 1919.
12. PRINGSHEIM und MAGNUS: HOPPE-SEYLER's physiol. Chem. **105,** 179, 1919.
13. VOLHARD: Landw. Versuchsstat. **58,** 433, 1903.
14. WAENTIG und GIERISCH: HOPPE-SEYLER's physiol. Chem. **103,** 87, 1918.
15. WAENTIG und GIERISCH: Z. angew. Chem. **I,** 173, 1919.
16. WILSTÄTTER und ZECHMEISTER: Ber. d. deutsch. chem. Ges. **46. II,** 2401, 1913.

APPENDIX

Excretion of faeces

1st period — Genge hay

1924	Temperature C°	Ram No. I.			Ram No. II.		
		Water drink L.	Fresh faeces g.	Dry faeces g.	Water drink L.	Fresh faeces g.	Dry faeces g.
September 26	23.5	1.8	754.5	251.5	3.15	654.8	224.2
27	23.5	1.65	791.5	275.9	3.20	657.3	223.2
28	22.0	1.80	647.2	247.9	3.00	607.5	226.7
29	22.7	1.90	746.9	274.8	2.95	665.3	238.6
30	23.0	1.95	665.7	254.8	2.75	717.3	243.1
October 1	23.3	1.90	663.5	235.9	2.40	858.5	280.8
2	25.0	2.10	634.0	241.0	3.30	924.1	281.3
3	25.3	2.20	572.0	230.9	3.40	975.0	277.6
4	25.0	2.05	658.0	266.6	3.20	835.0	243.1
5	24.5	2.10	678.0	268.5	3.00	673.0	232.1
Daily average	24.3	1.96	682.1	254.8	3.04	756.8	247.1

2nd period — Untreated straw

July 1924	Temperature C°	Ram No. I.			Ram No. II.		
		Water drink L.	Fresh drink g.	Dry faeces g.	Water drink L.	Fresh faeces g.	Dry faeces g.
22	28.5	2.80	683.0	275.6	3.35	549.0	240.7
23	29.7	2.70	601.0	254.9	3.65	601.5	247.2
24	30.0	2.40	660.0	274.6	3.40	632.0	279.3
25	30.3	3.10	598.5	256.0	3.50	552.5	241.8
26	29.0	2.25	623.0	254.4	3.25	628.5	259.5
27	30.3	2.90	614.5	259.1	3.25	582.5	234.7
28	30.5	3.15	618.0	238.5	3.65	577.0	223.4
29	30.3	2.60	779.0	288.7	3.15	548.0	213.1
30	30.5	3.30	635.0	245.8	3.85	709.0	243.9
31	30.5	3.10	686.0	236.8	3.10	683.5	246.9
Daily average	30.0	2.83	649.8	258.4	3.42	606.4	243.1

3rd period — Soda straw I (0.75 % NaOH)

October 1924	Temperature C°	Ram No. I.			Ram No. II.		
		Water drink L.	Fresh faeces g	Dry faeces g.	Water drink L.	Fresh faeces g	Dry faeces g
11	20.3	1.80	471.0	205.2	3.10	486.0	218.4
12	23.0	1.65	514.0	212.4	3.20	424.0	207.2
13	22.0	1.80	592.0	232.8	3.00	462.0	229.3
14	21.0	1.95	642.0	220.3	2.95	345.0	174.3
15	20.0	1.80	589.0	214.9	2.55	411.0	236.8
16	21.5	1.80	575.0	194.6	3.00	447.0	222.5
17	19.0	1.60	663.0	233.7	3.60	386.0	195.6
18	18.5	1.40	547.0	201.3	2.90	382.0	190.7
19	19.0	1.50	693.0	210.1	2.90	438.0	219.7
20	19.5	1.45	617.0	202.4	2.85	449.0	220.6
Daily Average	20.4	1.68	590.3	213.3	3.01	422.3	208.5

4th period — Soda straw II (1.5 % NaOH)

November 1924	Temperature C°	Ram No. I.			Ram No. II.		
		Water drink L.	Fresh faeces g.	Dry faeces g.	Water drink L.	Fresh faeces g.	Dry faeces g.
3	15.5	1.50	606.0	267.8	2.00	521.0	222.8
4	16.0	1.40	501.0	205.1	2.10	499.0	218.8
5	16.0	1.35	647.0	207.9	1.75	481.0	213.9
6	13.5	1.25	518.0	220.3	1.65	518.0	226.8
7	15 5	1.90	612.0	261.9	2.20	495.0	208.7
8	15.0	1.05	584.5	237.8	1.80	613.0	240.7
9	13.0	1.05	600.0	241.7	1.45	632.5	240.6
10	14.5	1.50	596.0	207.5	1.70	509.0	202.3
11	14.5	1.20	557.5	220.1	1.60	619.5	243.4
12	15.0	1.25	708.5	270.7	1.85	699.0	267.3
Daily Average	14.9	1.35	593.1	234.1	1.81	556.7	228.5

5th period — Lime straw (1 % CaO)

November 1924	Temperature C°	Ram No. I. Water drink L.	Ram No. I. Fresh faeces g.	Ram No. I. Dry faeces g	Ram No. II. Water drink L.	Ram No. II. Fresh faeces g.	Ram No. II. Dry faeces g.
18	15.0	1.40	581.5	210.3	1.60	657.5	235.2
19	17.0	1.55	785.5	256.1	1.80	640.5	261.4
20	18.0	1 35	983.5	218.5	1.60	651.5	273.3
21	16.5	1.20	860.0	251.6	1.80	578.5	231.8
22	13.5	1.40	982.0	267.5	1.55	687.5	279.2
23	12.0	1.15	920.0	249.8	1.25	706.4	283.4
24	13.0	1.40	983.0	269.6	1.65	553.5	214.4
25	13.0	1.30	871.0	254.5	1.70	793.0	288.7
26	14.0	1.35	849.0	241.0	1.70	624.5	258.1
27	14.0	1.30	974.0	277.7	1.85	647.5	273.5
Daily Average	14.6	1.34	874.5	249.7	1.65	654.0	259 9

6th period — Boiled straw

February 1925	Temperature C°	Ram No. I. Water drink L.	Ram No. I. Fresh faeces g.	Ram No. I. Dry faeces g.	Ram No. II. Water drink L.	Ram No. II. Fresh faeces g.	Ram No. II. Dry faeces g.
5	18.0	2.05	830.0	279.9	1.85	511.0	227.9
6	18.0	2.10	694.0	247.8	2.10	518.0	246.3
7	16.5	1.70	645.0	228.5	1.80	463 0	222.9
8	12.5	1.70	763.0	293.3	1.75	434 5	208.0
9	11.0	1.60	512.0	219.2	2.00	445.0	218.8
10	11.0	1.50	574.0	264.3	1.55	418.0	197.3
11	12.0	1.60	673.5	290.5	1.45	551.0	257.1
12	10.5	1.55	757.0	294.4	1.80	586.0	269.9
13	11.0	1.50	521.5	224.2	2 05	627.0	266.6
14	11.0	1.75	771.5	271.7	1.80	513.5	241.6
Daily Average	13.2	1.71	674.2	261.4	1.82	506.7	235.6

7th period Soda straw III

February 1925	Temperature C°	Ram No. I.			Ram No. II.		
		Water drink L	Fresh faeces g.	Dry faeces g.	Water drink L.	Fresh faeces g	Dry faeces g
20	11.0	1.70	751.0	295.6	1.80	601.0	252.6
21	11.5	1.65	836.0	313.7	1.70	690.5	279.4
22	11.0	2.00	787.0	282.1	2.05	643.5	314.1
23	5.5	1.60	818.5	249.0	1.20	597.5	261.2
24	7.0	1.50	671.5	252.2	1.30	624.0	271.8
25	6.0	1.20	784.0	267.6	1.40	605.5	266.1
26	7.0	1.70	794.5	292.8	1.55	594.0	262.3
27	6.5	1.65	817.5	272.9	1.40	577.0	246.2
28	7.0	1.35	867.5	302.0	1.85	634.0	272.0
May 1	8.0	1.70	810.5	275.9	1.70	724.5	288.5
2	8.5	2.75	796.5	248.7	2.90	652.5	281.0
3	9.5	1.80	781.5	256.2	1.65	728.5	270.5
Daily Average	8.2	1.72	793.0	275.8	1.71	639.4	272.1