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Whole Crop and Straw Silages Treated with Sodium Hydroxide for Feeding Beef Cattle

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Abstract

It is generally recognized that an application of sodium hydroxide (NaOH) is effective for improving nutritive values of low quality roughages and crop straws in ensiling as feeding stuffs. In the present study, oat whole crop, rice whole crop and rice straws treated with NaOH were subjected to evaluation in regard to their digestibilities in feeding and effects on live-weight gains and blood serum of beef cattle. Under an application of NaOH, the digestibilities of those materials were considerably increased. No significant differences in visual as well as chemical qualities were seen between the silages with and without NaOH-treatment. The blood serum analysis on the animals fed with NaOH-treated silages died not show any functional disorder. Most of the Na consumed by the animals was excreted through urine. The daily live-weight gains of the steers fed with NaOH-treated silages were satisfactory when a small amount of supplementary stuffs such as barley flakes and urea was added. These results suggest that beef production in Japan possibly be developed without heavily relying on imported grains but by applying NaOH to domestically produced feeding stuffs such as oat whole crop, rice whole crop or rice straws in ensiling them.

Discipline: Animal industry
Additional key words: blood serum constituents, daily live-weight gain, digestibility

Introduction

Studies with the purpose of improving nutritive values of crop residues by alkali treatment as feed stuffs have been undertaken extensively and intensively in various countries for a long time. In Japan, it was in 1926 to find out for the first time that the digestibility of rice straws was increased considerably when they were soaked in a lime solution before feeding[2]. This technique, however, was not accepted by the farmers in Japan due to its great labor requirements.

In European countries, sodium hydroxide (NaOH) has been used rather often for alkali treatment since 1894, while in Japan, the first use of NaOH started in 1979 in the method of dry process[5]. Sodium hydroxide solution was applied to rice straws at the time when those materials were pressed into cube by an ordinary hay cuber. This treatment provided increased digestibility of rice straws. In addition, it removed harmful effects of NaOH caused by strong alkali by changing entirely the residual NaOH, which was not combined with carbohydrate in straws, to Na_2CO_3. Such a rice straw cube treated with NaOH was produced in an ordinary hay cuber plant and the products were sold in a market in some areas, though not available at present.

In regard to ammonia treatment, some studies have been carried out on a laboratory scale since 1975[1]:

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Table 1. pH and organic acids concentrations of the NaOH treated and untreated silages of oat whole crop

	1979		1980	
	1.5% treated	Untreated	3.0% treated	Untreated
Moisture (%)	61.6	63.9	62.4	57.8
pH	5.21	4.85	5.50	4.86
Total acids (mg/100 g/silage)	1,824	1,780	2,139	2,131
Lactic	49	19	135	181
Acetic	117	94	213	208
Propionic	153	—	—	—
Butyric	1,149	1,200	1,352	1,319
Valeric	277	280	184	218
Caproic	81	188	256	206

Source: Ref. 6).

they have been followed by field experiments on stack system since 1978[4,8,9]. The stack system is now the most popular method for alkali treatment.

It is recognized that there are various advantages of adopting a method of adding NaOH in making silage. However, this method is not widely used yet in Japan. The reason for this negative use might be related to the anxiety on possible harms caused by strong alkali in using NaOH.

The authors have carried out a series of experiments on NaOH-treated silages since 1983[6-8]. This paper describes an outline of the results of those studies, in which oat whole crops[6], rice whole crops[7] and rice straws[8] were used as materials for making NaOH-treated silages.

Oat whole crop silage treated with NaOH[6]

The digestibility of the oat whole crop silage was significantly increased with an addition of NaOH solution while ensiling. With the raised levels of NaOH supply, the digestibility increased almost linearly. However, an adequate level of adding was presumed to be 3%, because visual quality of the silage was lowered occasionally beyond the level of 3%.

Chemical qualities of the silages treated with NaOH did not show any significant difference from the untreated silage (Table 1). It is likely that the relatively high pH in control silage was caused by a low moisture content. Silages treated with NaOH did not show extremely high pH, and the contents of lactic and volatile fatty acid were of the same level with that of the control silage. This implies that the residual NaOH which was not reacted with carbohydrate in oat plants was combined with CO_2 produced by silage fermentation (Table 2). The result in Table 2 indicates that nearly 40% of the added NaOH is combined chemically with oat carbohydrate, while the remaining portion is totally changed to Na_2CO_3-Na.

Table 2. Types and rates of residual Na in oat whole crop silage treated with NaOH

	1.5% treated	3.0% treated
Level of Na addition (%)	0.86	1.73
Residual Na (%)	0.56	1.08
Rate of residual Na to added Na (%)	64.97	62.81
Rate of types of residual Na (%)		
Na_2CO_3-Na	100	100
NaOH-Na	0	0

Source: Ref. 6).

As indicated above, harmful effect of NaOH due to strong alkali could be removed. However, a large amount of Na consumption might have some implications for mineral balance and functions of internal organs of animals. Tables 3 and 4 show the results of mineral balance and blood serum analysis, respectively. Twelve wethers were divided into three groups, 4 head each, and three types of silages were given to each group for 38 days. The feces and urine during the last 7 days were collected for analyses on mineral balance. Blood samples from each wether were taken on the last day of the experimental feeding.

Table 3. Mineral balance in wethers fed NaOH treated and untreated oat whole crop silages

	Untreated	1.5% treated	3.0% treated
Intake (g/day/wether)			
Na	0.45	4.58	11.93
K	4.39	6.14	6.65
P	0.51	0.87	0.85
Mg	0.45	0.52	0.57
Ca	0.73	0.81	0.85
Excreted in feces			
Na	1.19	1.88	1.60
K	3.67	0.74	0.78
P	1.21	1.34	1.23
Mg	0.42	0.31	0.25
CA	1.44	1.53	1.39
Excreted in urine			
Na	0.06	2.54	8.89
K	1.21	5.01	3.57
P	trace	0.01	0.01
Mg	0.09	0.07	0.10
Ca	0.22	0.02	0.02

Source: Ref. 6).

Table 4. Blood serum constituents in wethers fed oat whole crop silage treated with and without NaOH

		Untreated	1.5% treated	3.0% treated
Total prot.	(g/d*l*)	6.2	6.5	6.4
Albumin	(%)	64.2	63.7	69.5
Glucose	(mg/d*l*)	57	64	59
Urea-N	(mg/d*l*)	9.9	7.5	8.4
GOT	(KU)	54	57	53
GPT	(KU)	14	12	14
LDH	(WU)	707	961	811
ALP	(KA-U)	7.5	7.4	5.4
CPK	(IU)	18	16	30

Source: Ref. 6).

Table 3 indicates that most part of the Na consumed was removed through urine. A distinct difference was recognized in K balance: a remarkable decrease in K excretion through feces, while an increase in K excretion through urine. This difference may indicate that Na can substitute for K in the physiological function, and that a large amount of the Na intake causes a significant increase in K excretion through urine and a decrease of K content in saliva, resulting in the less excretion of K through feces. No clear differences in the balance of Ca, Mg and P were seen between the NaOH treated and untreated silages. Serum enzyme contents shown in Table 4 also indicate that a large amount of Na consumption does not affect the functions of internal organs. Table 5 shows the results of live-weight gains of holstein steers given oat whole crop silages treated with and without NaOH. The oat whole crop was harvested by a forage harvester, and NaOH solution was applied at an inlet of a blower. NaOH treated silages (1.5% in 1979 and 3.0% in 1980, respectively) were prepared in conventional tower silos together with an untreated silage for comparison.

Twelve steers were divided into two groups, 6 each: they were subjected to feeding with NaOH-treated and untreated silages, respectively. The same

Table 5. Digestibility, intake, and live-weight increase of steers fed oat whole crop silage treated with NaOH

	1979		1980	
	1.5% treated	Untreated	3.0% treated	Untreated
Digestibility (%)				
Dry matter	54.3*	50.2	56.6**	49.2
Crude protein	45.9*	42.5	57.4**	46.2
Crude fat	69.2*	64.9	71.8**	65.4
NFE	54.1	53.7	61.3**	54.9
Crude fiber	55.1*	50.4	53.0**	42.8
Intake (DM kg/day/steer)				
Silage	8.8	7.1	8.2	7.1
Barley flake	0.9	0.9	0.9	0.9
Urea	0.1	0.1	0.1	0.1
Weight increase (kg)				
Initial	326	318	315	335
Final	381	359	385	380
Daily gain	0.87*	0.65	1.00**	0.64
DM (kg/kg of D. G.)	11.2	12.3	9.1	12.0
TDN (kg/kg of D. G.)	6.2	6.6	5.4	6.7

* Significant between treated and untreated, $P < 0.05$.
** Significant between treated and untreated, $P < 0.01$.
Source: Ref. 6).

type of experiment was conducted in 1979 and 1980. The feeding result showed that greater consumption was seen in the NaOH treated silages in each experiment, though the difference was not large enough. Daily live-weight gains of steers fed with NaOH-treated silages were higher significantly than those with untreated silages.

The result in 1980 was especially satisfactory. It indicated that daily live-weight gain of 1.0 kg on an average could be achieved when oat whole crop silage treated with 3.0% of NaOH was given to holstein steers with an addition of a very small amount of supplement: 1.0 kg of barley flake and 100 g of urea.

Rice whole crop silage treated with NaOH[7]

The same type of experiment as above was conducted using silage of paddy rice. A distinct difference between oat and rice exists in a chemical component impeding digestibility, which is lignin in oat while silica in rice. However, the result of the experiment showed that the effect of NaOH treatment on the digestibility was the same between these two source materials of silages.

The digestibility of rice whole crop silage increased in an advanced stage of crop maturity as the case in oat crop silage. For rice silage, however, it is recommendable to harvest a little early prior to the fully matured stage, because rice straws turn too hard and moisture contents decrease greatly at the fully ripened stage, and these factors cause secondary fermentation after opening of silos. The type of Na in the rice crop silage and mineral balance measured in wethers showed the same results with those in oat whole crop silage. Blood constituent of steers fed with rice crop silage showed no harmful effects on the functions of internal organs just as the case in wethers fed with oat crop silages.

In order to suppress secondary fermentation of the silage, the following two measures employed were presumed effective: first, to harvest at a little early stage prior to the crop ripening so that moisture content of the crop could be maintained at 65–70%; second, to raise moisture content to the said level by watering the material together with a raised application of NaOH at a level of 4% in case where the moisture content was low due to the delayed harvest.

The results of the experiment undertaken with the purpose of confirming the above presumption are shown in Table 6. The rice plants were harvested by a special machine manufactured by the Hokkaido

National Agricultural Experiment Station, since a usual harvester for forages was not available in paddy fields.

Twelve holstein steers were divided into two groups, 6 head each, which were fed with the two types of silages as mentioned above, both of which were supplemented by 1 kg of barley flake and 200 g of urea for each steer. The quality of the silages was recognized excellent without any secondary fermentation.

The digestibilities of the two NaOH-treated silages were considerably higher than that of the untreated silage made at the late milky stage. The two NaOH treated silages were well accepted by the steers, and dry matter consumptions were almost equal each other. Daily live-weight gains in the two groups above were satisfactory: those of the two groups fed with the silages made at the late milky stage and the full ripened stage were 0.93 and 0.82 kg, respectively.

Rice straw silage treated with NaOH[8)]

There are two systems in utilizing paddy rice as feeding stuffs for beef cattle: one is a whole crop silage as mentioned above, and the other is a straw silage separated from cereal grains. The former system is more advantageous in saving labor since grains and straws are harvested at the same time. However, in case where the material is to be treated with NaOH, it is not necessary to include cereal grains for the treatment. For this end, the latter system has an advantage because a really needed amount of cereals could be given to animals in a mixed form with NaOH-treated straws, while feeding.

In the relevant experiment, rice grains were harvested by a combine harvester, husked and then ground. Fresh rice straws were baled by a small baler immediately after the harvest, and chopped by a forage harvester. The chopped materials were ensiled

Table 6. Digestibility, intake, and live-weight increase of steers fed rice whole crop silage treated with NaOH

	Late milk stage NaOH none	Late milk stage NaOH 3.1%	Full ripe stage NaOH 4.8%
Composition (%/DM)			
Moisture	63.3	64.7	65.1
Protein	8.4	7.4	6.5
Fat	3.0	2.7	2.2
NFE	55.8	56.7	55.9
Fiber	19.4	18.5	19.1
Ash	13.5	14.7	16.4
Digestibility (%)			
Dry matter	54.2**	58.6	59.4
Organic matter	59.0**	63.3	64.4
Protein	72.9**	65.6	64.1
Fat	70.6	77.4	73.6
NFE	67.5**	71.6	72.4
Fiber	36.5**	49.5	52.6
DCP	6.1**	4.6	3.8
TDN	55.6**	58.4	58.7
Intake (DM kg/head/day)			
Silage		8.11±0.47	8.32±0.94
Barley flake		0.86	0.86
Urea		0.20	0.20
Live-weight (kg/head)			
Initial		324.2±23.5	315.8±22.6
Final		385.4±28.7	369.8±28.4
Daily gain		0.93±0.23	0.82±0.16
DM (kg/kg of live-weight gain)		10.44±2.79	11.77±1.59

** Significant between NaOH-treated and untreated, $P < 0.01$.
Source: Ref. 7).

in a conventional tower silo with an addition of NaOH solution.

It is recognized very important to harvest rice plants to be able to get fresh and succulent straws. It would be easier to make a silage with dry and old straws by adding water. However, the silages produced in this way result rather often in poor quality and deteriorated feeding value. The low digestibility of ensiled materials is highly correlated with the poor quality of the silages.

Table 7 presents comparisons of chemical compositions, digestibilities and several other components between the rice straw silage treated with 4.96% NaOH and the low moisture grass silage. Twelve holstein steers, comprising two groups of 6 head each, were fed *ad libitum* with these two types of silages by supplementing 3 kg of ground husked-rice and 0.5 kg of fish meal per head. The result showed that the live-weight gain of the steers fed with the NaOH-treated rice straws was 0.92 kg per day, while that with the low moisture grass silage was 0.93 kg per day. This indicates that those two types of silages are equally high in their feeding value.

Table 7. Chemical composition, digestibility, intake, and live-weight increase of steers fed rice straw silage treated with NaOH

	Rice straw silage treated with NaOH	Grass silage
Composition (% / DM)		
Moisture	70.7	56.1
Protein	6.7	10.0
Fat	1.6	4.4
NFE	44.3	40.4
Fiber	29.2	35.3
Ash	18.1	9.9
Digestibility (%)		
Organic matter	62.8	57.6
Dry matter	57.5	56.6
Protein	31.3	51.7
Fat	43.2	78.7
NFE	61.5	51.9
Fiber	73.0	63.6
DCP	2.1	5.2
TDN	52.3	56.1
Intake (DM kg / head / day)		
Silage	4.27	4.23
Ground unpol. rice	2.58	2.58
Fish meal	0.46	0.46
TDN intake (kg / head / day)	4.96	5.10
DCP intake (kg / head / day)	0.49	0.62**
Live-weight (kg / head)		
Initial	310	326
Final	387	405
Daily gain	0.92	0.93
TDN (kg / kg of D. G.)	5.54	5.50
DCP (kg / kg of D. G.)	0.55	0.67**

** Significant between two silages, $P < 0.01$.
Source: Ref. 8).

Discussion

Paddy rice is the only cereal crop which is presently overproduced in Japan. Under the government policy, nearly 30% of the total paddy field is put in compulsory set-aside, including conversion to the field for other crops than rice. In order to maximize the utilization of land resources, two alternatives are proposed: one is rotational use of paddy fields for rice and other crops; and the other is consecutive cultivation of rice crop in paddy fields partly for producing rice-based animal feed. The latter alternative would be suitable particularly for the poorly drained areas, where upland field crops are not highly suited to be grown. In this connection, it should also be taken into account that paddy fields play an important role in Japan in preserving water resources. From this viewpoint, the consecutive cultivation might be more preferable than the rotational system.

At present, over 10 million tons of rice straws on a dry matter basis are produced every year in Japan. Such a huge amount of rice straws might have a great potential for supplying important feed resources with a high feeding value which is equivalent to low moisture grass silage, provided that they are treated with sodium hydroxide and supplemented by a small amount of stuffs such as barley flakes and urea. Rice straws have not been used effectively as an animal feed in this country in the past. One of the reasons relates to their low feeding value. This problem could be solved effectively and efficiently by treating rice straw silage with alkali. Since there are various methods for alkali treatment, farmers may use not necessarily NaOH but ammonia or urea for the same purpose at first.

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