Influence of Maceration Using a Screw-Type Threshing Combine on Roughage Value of Rice Straw in Japanese Black Cows

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Abstract : The roughage value of macerated rice straw (MRS) discharged from a combine harvester equipped with a screw-type threshing mechanism was evaluated. Test diets were prepared containing approximately 50% MRS or non-treated rice straw. The chewing activity of four Japanese black cows fed each diet sequentially was measured by behavior observation. The roughage value index (RVI) was 59.6 ± 11.3 min/kg for cows on the MRS diet and 71.2 ± 14.2 min/kg for those on the non-treated rice straw diet. No statistical differences in RVI values and time spent ruminating were found between the two groups, though the total time spent eating in the MRS group was shorter ($p< 0.05$) than that of the control group. The results indicate that the roughage value of MRS is equivalent to that of typical roughage even with the shortened eating time, when the containing ratio of MRS in the diet is approximately 50%.

Key Words : Cattle, Macerate, Rice straw, RVI

汎用コンバインを用いた圧砕処理が黒毛和種雌牛における稲わらの粗飼料価に及ぼす影響：

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抄　録：汎用コンバインを用いて調製した圧砕稲わらの粗飼料価を評価した。圧砕稲わら或いは無処理稲わらを約50%含む試験飼料を4頭の黒毛和種雌牛に給与し、行動観察により咀嚼時間を測定した。圧砕稲わら区および対照区における粗飼料価指数（RVI）はそれぞれ59.6 ± 11.3 min/kg或いは71.2 ± 14.2 min/kgであり、RVIおよび反芻時間について統計的な差はみとめられなかったが、圧砕稲わら区の採食時間は対照区に比べて短く（$p<0.05$）なった。これらの結果は、飼料組成中の割合が約50%では、圧砕稲わらは採食時間が短くなるものの、粗飼料価は代表的な粗飼料のそれと同等であることを示している。

キーワード：ウシ、稲わら、圧砕処理、粗飼料因子

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Ⅰ Introduction

In many parts of the world, rice straw is an important source of roughage for ruminants. The Japanese government has promoted the use of rice straw as forage to increase the country's self-supplying feed rate of livestock. However, the rate of rice straw used for forage has remained approximately 10%（Food Safety and Consumer Affairs Bureau 2009）. One of the issues preventing the use of rice straw for forage may be the difficulty of wilting the straw during harvest（Enishi 2002）. Accordingly, to shorten the wilting period, Otani *et al.*（2009）have developed a method for macerating rice straw using a combine harvester equipped with a screw-type threshing mechanism. The characteristics of the macerated rice straw（MRS）such as the roughage value may not be the same as those of conventional rice straw. The present study attempted to evaluate the roughage value of MRS by comparing it with the roughage value of conventional rice straw.

Ⅱ Material and Methods

1 Animals

Four Japanese black cows（mean bodyweight, 413 ± 40 kg; mean age, 9 ± 4 years）were used. Cows were housed individually and tied loosely in pens with chains. Animals were handled in accordance with the Guide for the Care and Use of Experimental Animals（National Agricultural Research Center for Tohoku Region）.

2 Processing of rice straw

The rice variety Akitakomachi was cultivated in a paddy field at the National Agricultural Research Center for the Tohoku Region（Morioka, Iwate）. Two types of rice straw were processed by the two procedures.

For processing one type of rice straw, the rice was harvested at the full ripe stage using a head-feeding combine（AR43, Kubota, Osaka, Japan）, and rice straw was then discharged onto the paddy field. After 8 days of wilting with tedding by a rotary rake（GA320GM, Kuhn, Saverne, France）, the discharged rice straw was then raked into windrows. The rice straw was then baled and wrapped using a trailer-type round baler（2210W, IHI STAR Machinery Corporation, Chitose, Japan）and a bale wrapper（WM1550R, Takakita Co., Ltd., Nabari, Japan）（non-treated rice straw）.

To process the other type of rice straw, the rice was harvested using an axial-flow combine with a screw-type threshing mechanism（ARH 900, Kubota, Osaka, Japan）with a windrower attached and the straw cutting unit removed. The rice straw was then macerated by the screw-type thresher of the combine and discharged onto the paddy field. After 3 days of wilting without tedding, the macerated rice straw（MRS）was baled and wrapped as described for the non-treated rice straw.

3 Chemical analyses

The moisture content of the rice straw was determined by drying the samples at 70° C for 48 h. The neutral detergent fiber（NDF）and acid detergent fiber（ADF）contents were determined by conventional methods（Association of Self-supply Feed Evaluation 2001）. The organic cell wall（OCW）and organic cell contents（OCC）were determined using the methods described by Abe *et al.*（1979）.

4 Diets and measurement of chewing time

Experimental diets consisted of 1.5 to 1.7 kg（dry matter; DM）of ground unhulled rice, 0.5 to 0.6 kg（DM）of soybean meal, and either 2.1 to 2.2 kg（DM）of MRS（MRS diet）or 2.0 kg（DM）of non-treated rice straw（control diet）. The DM basis ratio of roughage to concentrate feed in both diets was approximately

one to one. Half the mixture ration was given twice daily at 0930 and 1600 hours. Cows were given the MRS diet from days 1 to 12 and the control diet from days 13 to 24.

The behavior of the cows was recorded for 24 h (from 1600 hours) on day 11 and again on day 23. Four color CCD cameras (WAT-230A, Watec, Tsuruoka, Japan), a switcher (WAT-SWC4, Watec), and a DVD recorder (DVR-330H, Pioneer Corporation, Tokyo, Japan) were used. Pictures from the CCD cameras set in front of each cow were captured by the switcher and edited into one picture. The edited picture was recorded by the DVD recorder. Time spent eating and ruminating for each cow was measured by the recorded picture. The roughage value index (RVI) was calculated using the following equation: RVI (min/kg) = time spent chewing (eating + ruminating) /DM intake.

5 Statistical analyses

The student's t-test was performed to test significant differences between the chemical compositions of MRS and those of non-treated rice straw. The paired student's t-test was performed to test significant differences between the groups of RVI, total time spent eating, and total time spent ruminating.

Ⅲ Results

All animals consumed all of the given feed during the experimental period. Total DM intake of the control group was in the range of 4.0 to 4.3 kg/day, while the total DM intake of the MRS group was in the range of 4.1 to 4.5 kg/day. No difference was observed between the chemical compositions of MRS and those of the non-treated rice straw (Table 1).

Table 1 Chemical composition of rice straws

	Moisture	Crude protein	Ether extract	OCW	OCC	NDF	ADF	Crude ash	Silica
	(% of FM)	(% of DM)							
Non-treated rice straw	15.1 ± 1.0	3.7 ± 0.4	0.9 ± 0.4	65.7 ± 0.3	17.5 ± 0.8	64.0 ± 2.1	38.7 ± 0.1	16.8 ± 0.7	12.1 ± 0.7
MRS	8.6 ± 0.3	3.3 ± 0.4	0.9 ± 0.2	66.0 ± 2.2	17.4 ± 1.8	63.5 ± 2.1	38.6 ± 1.0	16.6 ± 0.3	11.6 ± 0.7

Values are mean ± standard error of three replicates.
DM : Dry matter, FM : Fresh matter, MRS : Macerated rice straw

The total time spent eating of the MRS group (19.2 ± 3.2 min/kg) was shorter ($p < 0.05$) than that of the control group (22.2 ± 3.2 min/kg). The total time spent ruminating was 40.4 ± 9.5 min/kg for the MRS group and 49.0 ± 13.1 min/kg for the control group. No statistical difference was found between the two groups. The RVI for the MRS group (59.6 ± 11.3 min/kg) as tended to be smaller than that of the control group (71.2 ± 14.2 min/kg), but no statistical difference was found between the two groups (Fig. 1).

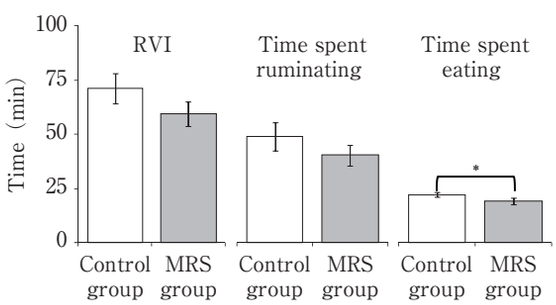

Fig. 1 Comparison of RVI, time spent ruminating, and time spent eating for the control and macerated rice straw groups

Vertical bar indicates standard error of four replicates.
MRS: Macerated rice straw.

Asterisk represents a significant difference between the two groups.
*: $p < 0.05$

Ⅳ Discussion

In the present study, no difference was observed between the chemical compositions of MRS and those of the non-treated rice straw. The result indicates that maceration does not change the chemical composition of rice straw. Sudweeks *et al.*（1981）have found that the physical characteristics of feed are quantitatively reflected in the chewing behavior of ruminants. Accordingly, they devised the RVI to represent the total chewing time per kilogram of DM. The chewing time consists of eating time and ruminating time. In the present study, the total time spent eating was shortened in the MRS group. The physical characteristics of MRS were not measured in the present study, but the change in the physical properties of the rice straw such as the rigidity that prolongs the eating behavior by maceration could be presumed. Enishi（2002）has reported that the RVI of rice straw is approximately 90 min/kg in fattening Japanese Black cattle given rice straw at the rate of 60% of total feed. As compared to his RVI, the RVI values in both the MRS and control groups of the present study were small. The containing ratios of rice straw in the MRS and control groups of the present study were approximately 50%. Sudweeks *et al.*（1981）have proposed that the RVI of mixed feed could be calculated using the RVI of individual feed ingredients and the mixing ratio. It is most likely that the difference between the RVI reported by Enishi and RVI of the present study is caused by the difference in the containing ratio of rice straw in the total feed. Furusawa *et al.*（2004）have reported RVI values of 77.6 ± 12.7 min/kg, 70.7 ± 9.1 min/kg, and 63.5 ± 7.4 min/kg for rice straw, whole crop rice silage, and timothy given to Japanese black cows at a rate of 35% of total feed. The present results indicate that the roughage value of MRS is equivalent to that of typical roughage, even with shortened eating time, when the containing ratio of the MRS in diet is approximately 50%.

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