

## Effect of Hull-Splitting in Rice on the Digestibility of Grain in Whole Crop Silage

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### Abstract

Low digestibility of rice grain silage is a serious problem in effective utilization of rice plants as whole crop silage. This study examined the effect of hull-splitting rice spikelets on this digestibility. Hull-splitting unhulled spikelets collected from an experimental strain, which shows consistently a high frequency of hull-splitting, were processed to silage, and inserted into the rumen of a fistulated dry cow, together with brown rice grains and other materials as control. The degree of digestibility was evaluated as percentage of reductions in dry and organic matters after the *in situ* digestion. Results showed no advantages of hull-splitting for the digestibility, probably due to the inhibiting effect of the materials deposited on the surface of brown rice grains. Other strategies, such as the development of genotypes with large vegetative organs and small panicles, are recommended.

### 1. Introduction

Recently in Japan, there is a growing trend to utilize rice plants as whole crop silage to feed cattle or other domestic ruminants<sup>(1)</sup>. When rice plants are cultivated as feed for whole crop silage (feed rice), many novel characteristics have to be taken into account for this purpose, that is, nutritional value as a feed crop, palatability to domestic animals, availability for making silage, etc. Although most of the nutritional requirements for rice as a feed crop appear to be satisfied<sup>(2, 3)</sup>, one of the most serious problems for the utilization of rice plant as silage is the low digestibility of rice grains, in which most of the nutrition is accumulated<sup>(4, 5)</sup>. Because the grain of brown rice is tightly covered with a palea and lemma, both of which are composed of low-digestible silica-rich tissues, the digestive enzymes of cattle cannot access the surface of brown rice grains sufficiently. Consequently, a considerable proportion of the grains of feed rice tend to be excreted in an undigested form. The percentage of undigested grains has been reported as approximately 10-60%<sup>(4)</sup>.

One of the rice characteristics that could serve the above problems of digestibility is hull-splitting of the spikelet, in which a fine split appears between the palea and lemma. The surface of a brown rice grain with this hull-splitting spikelet has more chance to be penetrated and digested by enzymes passing through this split, probably leading to better digestibility. Hull-splitting of the spikelets was originally regarded as an inferior characteristic because it increases the rate of insect damage, which results in poor quality brown rice. Thus, this characteristic has been eliminated in most rice-breeding programs.

This study examined whether hull-splitting spikelets can contribute to the improvement of the digestibility of spikelet-containing feed rice. One experimental strain was found that showed a high frequency of spikelets that exhibited hull-splitting. This strain was evaluated for the degree of digestibility with *in situ* digestion procedures using fistulated dry cows.

### 2. Materials and Methods

An experimental strain of rice (*Oryza sativa* L.), T13, was derived from a cross between a large grain cultivar, BG 1, and a small grain cultivar, Koshihikari. T13 shows slightly longer grains than Koshihikari, and a consistent high frequency of hull-splitting in many spikelets. Figure 1 exemplifies the spikelets of T13 showing hull-splitting. The maximum width of the split between the palea and lemma was approximately 0.5 mm.

In 2001, T13 was grown at a paddy field at Hiroshima Prefectural University, Shobara, Hiroshima, Japan, using

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ordinary cultivation practices for this region. Around 30 days after heading, which is the recommended stage for silage processing of rice, whole plants above the ground were harvested and immediately cut into pieces of about 10 cm in length. These materials were put nylon bags of 15×30cm, degassed with an aspirator, and sealed tightly. These sealed bags were kept in the dark and in low-temperature conditions to ensure anaerobic fermentation.

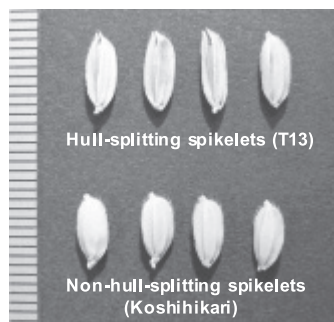


Fig. 1. Hull-splitting (T 13) and non-hull-splitting (Koshihikari) rice spikelets.  
A scale at the left indicates 1 mm.

In the same paddy field and during the same growing season the spikelets of Hoshiyutaka, a standard Japanese feed rice cultivar for whole crop silage, were harvested at about 45 days after heading. Half of the harvested spikelets were hulled using a manual huller to obtain brown rice. The brown rice and unhulled spikelets were each mixed with whole rice plants of another cultivar, Kusanohoshi, harvested at about 30 days after heading. Whole plants of Kusanohoshi, excluding spikelets, were cut into pieces as with T13. These materials were packed into nylon bags, prepared as whole-crop silage as above, and used as a control with hull-splitting spikelets of T13. Hoshiyutaka brown rice and unhulled spikelets were used as controls because of the shortage of spikelets of T13. In addition, the vegetative organs of Kusanohoshi were used instead of those of Hoshiyutaka, because the latter were too late to process as silage.

After about three months from silage processing, the brown rice of Hoshiyutaka, unhulled spikelets of Hoshiyutaka, hull-splitting spikelets of T13, and non-hull-splitting spikelets of T13 were collected as processed silage from the nylon bags. As a control, maize kernels and soybean meal, both of which are standard fodder available from feed companies, were used following the same procedure. Each of the four materials and two fodder controls were halved, counted and weighed to determine their fresh weight. One half of each sample was dried in an oven at about 65°C for two days to measure the dry weight of non-digested control. The other half of each sample was packed into nylon mesh bags (15×8cm, mesh size 45µm). These bags were closed tightly and inserted into the rumen of a fistulated dry cow.

After 48 hours, the inserted materials were withdrawn, washed well with tap water, and dried in an oven at about 65°C for two days to measure dry weight after digestion. In addition, these dried materials were combusted in an oven, and weighed again to measure the resulting ash weight. Three fistulated dry cows of the same age and similar condition were used three times with two-week intervals as replicates.

All data as percentages were converted using arc sine transformation. Analysis of variance according to a split-plot design with three replicates was conducted, with fistulated dry cow as the main plot and digested material as the sub-plot. Both the fistulated dry cows and digested materials were considered to be fixed effects.

### 3. Results and Discussion

Highly significant differences were found among the six kinds of digested materials, while the differences among the three cows and three replicates were not significant, in both percentage of reductions in dry matter and organic matter (Table 1). The interactions between cow and digested material were also significant for both traits. However, the order of the six digested materials did not change among the three cows for both percentages (data not shown).

No significant difference was obtained between non-hull-splitting and hull-splitting spikelets of T13 in the percentage of reduction in dry matter or organic matter (Table 2). These percentages for T13's spikelets were very low, although the fodder controls were mostly digested in the same rumens. These results showed that the hull-splitting of

spikelets in the present materials did not improve the digestibility of spikelet silage. In addition, brown rice silage also showed significantly lower digestibility than both maize and soybean fodders, though it was much higher than the unhulled spikelet silage (Table 2). These results indicated that the digestibility of hull-splitting unhulled-spikelet silage could not attain a sufficient level to be used as a fodder material, even if spikelets with wider splitting hulls are developed. Some materials in the outer-most layer of brown rice, in which proteins, lipids, minerals, etc., are mainly accumulated, might inhibit the digestion of brown rice in the rumen. In digestive organs of a cow, fed materials are ruminated again and digested additionally through several organs other than rumen. The *in situ* digestion procedure adopted in the present study can evaluate the digestibility only in the rumen. The actual degree of digestibility would be higher than the results in Table 2. The effect of hull-splitting, however, might not be evident in the whole digestive process, because the degrees of digestion found in hull-splitting and non-hull-splitting spikelets were very similar (Table 2).

Table 1. Analysis of variance of the percentage of reductions in dry matter and in organic matter after *in situ* digestion of rice spikelet silage and control fodder in the rumens of fistulated dry cows.

Source	df	Mean square	
		% reduction in dry matter	% reduction in organic matter
Trial (Block)	2	11.20	8.71
Fistulated dry cow	2	11.94	13.20
Residual of main plot	4	3.08	2.27
Digested material	5	8749.39**	6651.10**
Cow×Material	10	11.94**	10.65**
Residual of subplot	30	2.80	2.45

\*\* Significant at the 0.01 probability level.

Values after arc sine transformation are presented.

Table 2. Percentage of reductions in dry matter and organic matter after *in situ* digestion of rice spikelet silage and control fodders in the rumens of fistulated dry cows.

Digested material	Percentage of reduction in <sup>1</sup>	
	Dry matter	Organic matter
Maize kernel fodder	82.4 <sup>b</sup>	82.7 <sup>b</sup>
Soybean meal fodder	99.2 <sup>a</sup>	99.3 <sup>a</sup>
Brown rice silage of Hoshiyutaka	69.7 <sup>c</sup>	70.2 <sup>c</sup>
Unhulled spikelet silage of Hoshiyutaka	4.0 <sup>e</sup>	12.3 <sup>e</sup>
Non-hull-splitting unhulled-spikelet silage of T13	8.5 <sup>d</sup>	16.9 <sup>d</sup>
Hull-splitting unhulled-spikelet silage of T13	7.6 <sup>d</sup>	15.5 <sup>d</sup>

<sup>1</sup>Percentages with a common superscript letter are not significantly different (df=30,  $P<0.01$ ) according to F-protected Fisher's LSD.

The present results failed to detect any advantages of hull-splitting spikelets for improvement of the digestibility of rice grains. Another strategy to resolve this problem could be crushing the grains during silage processing<sup>(5)</sup>. The development of genotypes that accumulate photoassimilates mainly in vegetative organs (leaf blades, sheaths, and culms) and not in reproductive organs (endosperm cells) also be an effective strategy. Matsumura<sup>(6)</sup> demonstrated a wide genetic variation in the degree of accumulation of nonstructural carbohydrates in leaf sheaths and culms in mature rice plants. Several new cultivars, such as “Kusanohoshi”, “Hamasari”, etc., could match this profile to be used as feed rice<sup>(1)</sup>. Kato et al.<sup>(7)</sup> also proposed that rice strains showing genetic female sterility could be used as a material for whole crop silage. An F<sub>1</sub> hybrid cultivar produced with a cytoplasmic male sterile line and a line without restorer genes could also be a candidate as a type of feed rice, in which hybrid vigor is expressed only in the vegetative organs.

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## 和文抄録

### 発酵粗飼料としての稲粃の消化性に及ぼす割れ粘性の効果

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現在日本国内で、やや早刈りした稲体全体をサイレージ（発酵粗飼料）として調整し、乳牛等の飼料とすることが試みられている。これに対応した飼料イネ用品種の育成、飼料イネ栽培・調整技術の開発等が進展しているが、重大な問題の一つとして、栄養価の高い粃の消化率が低く、粃がそのままの形で糞便とともに排出されることが挙げられる。本研究は、粃の消化性を向上させる一手段として、イネ穎花の外穎と内穎間に約 0.5mm 程度の隙間が生じ、玄米表面と胃液との接触機会が増加する割れ粘性に注目した。そこで、品種・系統間交雑に由来し、遺伝的に高い割れ粘性を示すイネ系統を用いて、その割れ粃および玄米と非割れ粃をサイレージに調整し、フィスティル装着乾乳牛の第一胃内に 48 時間挿入して乾物重および有機物の減少率から消化率を推定した。その結果、割れ粃と非割れ粃はともに消化率が低く、割れ粃の消化率向上効果は乏しいことが明らかになった。また、玄米もトウモロコシ子実等他の飼料にくらべ消化率が低いことから、玄米表面に何らかの消化阻害物質が存在すると推察された。今後は、例えば、出穂後生産された同化産物を穂にではなく茎葉に貯蔵するようなイネ品種を開発することが、飼料イネサイレージの飼料価値を高める上で重要であると思われる。

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