FERMENTATION QUALITY AND NUTRITIVE VALUE OF BARLEY STRAW AND WET BREWERS' GRAINS SILAGE

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Summary

Three experiments were carried out to evaluate the fermentation process and subsequent nutritional quality of silage made from dried and fresh barley straw with and without the addition of wet brewers' grains. The treatments were: 1 kg of dried straw with 600 g of water but no wet brewers' grains (Ⅰ-0) as a control, and the same straw mixed with 2 kg (Ⅰ-2), 3 kg (Ⅰ-3), 4 kg (Ⅰ-4), or 5 kg (Ⅰ-5) of wet brewers' grains as treatments in Experiment Ⅰ; and 2 kg of fresh straw without wet brewers' grains (Ⅱ-0) as a control, and the same fresh straw mixed with 2 kg (Ⅱ-1), 4 kg (Ⅱ-2), 6 kg (Ⅱ-3), or 8 kg (Ⅱ-4) of wet brewers' grains as treatments in Experiment Ⅱ. Each material prepared was ensiled in 5 L (vinyl) bag silos, and the silos placed in a chamber of 21℃ for 10 (Exp. Ⅰ) or 7 (Exp. Ⅱ) months. The fermentation quality and nutritive value of the barley straw silages produced were markedly improved by mixing them with wet brewers' grains. Increasing levels of wet brewers' grains caused on increase in fermentation quality. The *in vitro* dry matter digestibility of silages was also increased by adding wet brewers' grains. Two semi scale pilot silages, experiment Ⅲ, prepared from dried and fresh barley straw mixed with wet brewers' grains were fed to wether sheep. These silages, which contained 50% barley straw and 50% wet brewers' grains by dry weight, were moderate apparent digestibility and supplied of about 50% TDN and 10% DCP.

(**Key Words**: Barley Straw, Wet Brewers' Grains, Silage, Fermentation, Nutritive Value)

Introduction

Many processing or pretreatment methods (physical, chemical, physico-chemical and biological) can improve the feeding value of lignocellulosic by-products by increasing their digestible energy content or feed intake (Doyle et al., 1986).

Supplementation or ensilage with other palatable materials, especially agroindustrial by products or green forages, has been used in developing countries in Asia for improving the contents of available nitrogen and carbohydrates to supply a sufficient nutrients for maintenance of animals (Doyle et al., 1986; Kamra and Zadrazil, 1988). Such ensiling has been found to enhance fermentation quality and to produce a maintenance diet for rams or cattle (Krishna, 1982; Mandal et al., 1989).

The use of brewers' grains, dried or wet, as a feed resource for both monogastric and ruminants has been reported (Murdock et al., 1981; Deltoro Lopez et al., 1981; Davis et al., 1983; Uchida et al., 1983; Rogers et al., 1986). Wet brewers' grains usually have a low crude fibre, high crude protein and high digestibility, but low storability. On the other hand, barley straw as a lignocellulosic by-product contain high crude fibre, low crude protein and low digestibility.

Ensiling barley straw with wet brewers' grains can therefore be expected to improve the fermentation quality and nutritive value of the mixture. Wet brewers' grains as a carbohydrate source can provide an adequate substrate (water soluble carbohydrate/WSC) to accelerate the growth of lactic acid bacteria and to establish rapidly acid conditions in the silage. At the same time it will increase the crude protein content and decreased the fibrous component, thus possibly increasing the digestibility of the silage.

The experiment reported here was conducted to evaluate the fermentation quality and nutritive value of silages made from mixtures of barley straw and wet brewers' grains. A feeding trial using three mature wether sheep was carried out to study the apparent digestibility of two of the silages.

Materials and Methods

Silage production

Barley straws were collected from a farm and

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wet brewers' grains were taken from a company (Futaba Shiryo Co. Ltd.), in Okayama prefecture, on June 6, 1990 for experiment Ⅰ, and on June 2, 1991 for experiment Ⅱ. The barley straw for experiment Ⅰ was dried to 82.5% dry matter before using. After being chopped into 1.3 cm lengths, the barley straw was lacerated by a chopper-cracker (Taninaka, Co. Ltd.) until almost pulp. The chemical composition of the raw materials for ensiling is shown in table 1. The processed and wet brewers' grains were mixed in different proportions, and the various straw-grains mixtures ensiled in vinyl-bag silos of 5 litre capacity from which air was excluded using a vacuum pump.

TABLE 1. CHEMICAL COMPOSITION AND *IN VITRO* DRY MATTER DIGESTIBILITY OF BARLEY STRAW AND WET BREWERS' GRAINS MATERIALS

	Experiment Ⅰ		Experiment Ⅱ	
	Dried barley straw	Wet brewers' grains	Fresh barley straw	Wet brewers' grains
Dry matter (g/kg)	824.9	273.3	262.4	248.2
Protein (g/kg DM)	26.4	262.8	27.4	266.5
Ash (g/kg DM)	44.9	30.7	67.2	33.7
Crude fibre (g/kg DM)	479.6	119.1	418.9	109.6
NDF (g/kg DM)	806.9	512.9	751.6	559.1
ADF (g/kg DM)	516.2	165.3	488.6	192.7
Lignin (g/kg DM)	64.1	37.4	85.7	44.5
Silica (g/kg DM)	14.2	9.5	13.9	9.5
Cellulose (g/kg DM)	452.1	127.9	402.9	148.2
Hemicellulose (g/kg DM)	290.7	347.6	263.0	366.4
WSC (g/kg DM)	45.4	196.6	36.8	138.4
IVDMD[1] (%)	35.0	65.9	42.6	62.1
IVDMD[2] (%)	51.6	68.1	49.9	63.0

Abbreviation: NDF = Neutral detergent fibre, ADF = Acid detergent fibre, WSC = Water soluble carbohydrate, IVDMD = *In vitro* dry matter digestibility

Hemicellulose = NDF − ADF. Cellulose = ADF − Lignin.

[1] Abe and Horii method.

[2] Tilley and Terry method.

Silage production was divided into two experiments (Ⅰ and Ⅱ). The ingredients for experiment Ⅰ were 1 kg dried barley straw with 600 g water without wet brewers' grains (Ⅰ-0) as a control, and 1 kg dried barley straw with 2 kg (Ⅰ-2), 3 kg (Ⅰ-3), 4 kg (Ⅰ-4), or 5 kg (Ⅰ-5) of wet brewers' grains. The silage materials for experiment Ⅱ were 2 kg fresh barley straw without wet brewers' grains (Ⅱ-0) as a control, and 2 kg fresh barley straw with 2 kg (Ⅱ-1), 4 kg (Ⅱ-2), 6 kg (Ⅱ-3), or 8 kg (Ⅱ-4) of wet brewers' grains.

Each silo was placed in a constant temperature chamber at 21℃ for 10 (Exp. Ⅰ) and 7 (Exp. Ⅱ) months of storage. At the end of the storage period, the silos were opened and the mouldy part (upper 1/4 and bottom 1/4) of each silage was discarded before sampling. The samples were frozen at −32℃ for further analysis.

Chemical analysis

Dry matter (DM) content of silages was determined using a freeze and vacuum dry method (Uchida, 1986), and raw material was dried by oven at 55℃. The dried samples were ground and then crude ash, crude protein and crude fibre were determined accoding to AOAC (1992). Neutral detergent fibre, acid detergent fibre, lignin and silica were determined by the method of Goering and Van Soest (1970). *In vitro* dry matter digestibility (IVDMD) was determined by both the method of Abe and Horii (1974), and the method of Tilley and Terry (1963). The content of water soluble carbohydrate (WSC) in the raw materials and the silages was evaluated using the method of Deriaz (1961). Water extracts from fresh silages were prepared for measuring pH, lactic acid (Barker and Summerson, 1941), volatile fatty acid and ethanol (Uchida and Hayashi, 1985).

Determination of apparent digestibility value

Two silages used for digestion trial were made from the same materials with the experiment Ⅰ and Ⅱ (Experiment Ⅲ). These silages which contained a mixture of dried (treatment Ⅰ/FⅠ) or fresh (treatment Ⅱ/FⅡ) barley straw and wet brewers' grains were ensiled into semi field scale silos. The mixing rate was about 1 : 1 by dry weight (dried barley straw 1 : wet brewers' grains 0.99 in FⅠ, fresh barley straw 1 : wet brewers' grains 0.95 in FⅡ). The silages were stored for 12 (FⅠ) and 10 (FⅡ) months. Silage samples for laboratory analysis were prepared from the upper, middle and bottom parts of each silo with the corresponding to feeding trial.

Three mature wether sheep, weighing 46.0-49.5 kg, were used to determine the apparent digestibility of FⅠ and FⅡ silages, respectively. The silages were fed at a level of 1.8% (FⅠ) and 1.5% (FⅡ) of liveweight. The diets were fed twice a day in equal amounts at 08:00 and 15:00 hours for 10 days of a preliminary period and 7 days of a collection period. Water and mineral block were available at all times. Fecal samples were prepared according to the total collection method.

Silage samples were determined using the same method with the experiment Ⅰ and Ⅱ, while fecal samples were determined using the same method with the raw materials samples.

Results and Discussion

Silage quality

The fermentation quality, chemical composition and *in vitro* dry matter digestibility of mixture silages are shown in table 2, 3 and 4, respectively.

Silages containing wet brewers' grains in experiment Ⅰ and Ⅱ were well preserved and had lower pH ($p < 0.01$) and higher lactic acid concentrations ($p < 0.01$) than the silage made only from barley straw. The fermentation quality of mixture silages was significantly ($p < 0.01$) improved by increasing the level of wet brewers' grains (table 2).

TABLE 2. FERMENTATION QUALITY OF BARLEY STRAW AND WET BREWERS' GRAINS SILAGES (EXPERIMENT Ⅰ AND Ⅱ)

Treatments	pH	Lac.	Eth.	C2	C3	*i*-C4	*n*-C4	*i*-C5	*n*-C5
		(g/kg DM)							
					Experment Ⅰ				
Ⅰ−0	5.5	7.3	0.3	0.9	1.7	2.5	2.7	0.1	0.1
Ⅰ−2	4.1	20.5	4.8	12.2	0.4	0.2	0.0	0.0	0.0
Ⅰ−3	4.0	26.7	6.0	16.2	0.5	0.3	0.0	0.0	0.0
Ⅰ−4	3.9	34.1	8.8	13.5	0.7	0.2	0.0	0.1	0.0
Ⅰ−5	3.9	37.3	10.2	19.5	0.7	0.3	0.0	0.0	0.1
Sig.[a]	**	**	**	**	**	*	*	NS	NS
					Experiment Ⅱ				
Ⅱ−0	4.4	34.5	1.7	6.2	0.8	0.2	0.4	0.8	0.3
Ⅱ−1	3.9	63.4	9.6	13.4	0.8	0.2	0.1	0.0	0.0
Ⅱ−2	3.9	66.4	15.3	18.2	2.1	0.2	0.1	0.0	0.0
Ⅱ−3	3.8	73.8	13.8	17.8	2.5	0.2	0.2	0.0	0.0
Ⅱ−4	3.7	67.2	14.0	20.0	1.5	0.5	0.1	0.0	0.0
Sig.[a]	**	**	**	**	*	NS	**	**	*

Abbreviation: Lac. = Lactic acid, Eth. = Ethanol, C2 = Acetic acid, C3 = Propionic acid, *i*-C4 = iso Butyric acid, *n*-C4 = normal Butyric acid, *i*-C5 = iso Valeric acid, *n*-C5 = normal Valeric acid.

[a] Significant difference: NS $p > 0.05$, * $p < 0.05$, ** $p < 0.01$.

It is assumed that the addition of wet brewers' grains supplied available carbohydrate as a readily usable energy substrate to stimulate the good fermentation by lactic acid bacteria. This is in

TABLE 3. CHEMICAL COMPOSITION AND *IN VITRO* DRY MATTER DIGESTIBILITY OF BARLEY STRAW AND WET BREWERS' GRAINS SILAGES (EXPERIMENT I AND II)

Treatments	DM	CP	Ash	CF	WSC	IVDMD[1)]	IVDMD[2)]
	(g/kg)	(g/kg DM)				(%)	
				Experiment I			
I −0	662.7	17.4	48.6	494.3	10.6	31.4	45.4
I −2	532.6	110.6	45.3	375.4	17.6	44.7	48.6
I −3	456.9	146.3	43.7	328.5	18.9	48.4	49.9
I −4	395.9	170.8	43.3	311.5	15.8	52.9	49.0
I −5	377.0	188.6	41.9	291.7	19.9	53.3	49.9
Sig.[a)]	**	**	**	**	**	**	**
				Experiment II			
II −0	266.7	24.6	72.8	461.7	17.6	38.6	48.4
II −1	255.5	151.2	53.8	295.0	19.9	48.1	53.1
II −2	246.8	198.3	46.1	256.0	20.6	52.6	54.4
II −3	223.5	227.6	44.6	225.8	21.2	56.2	53.3
II −4	248.6	239.5	39.9	208.7	19.8	58.1	55.3
Sig.[a)]	*	**	**	**	**	**	**

Abbreviation: DM = Dry matter, CP = Crude protein, CF = Crude fibre, WSC = Water soluble carbohydrate, IVDMD = *In vitro* dry matter digestibility.

[1)] Abe and Horii method.

[2)] Tilley and Terry method.

[a)] Significant difference: NS $p > 0.05$, * $p < 0.05$, ** $p < 0.01$.

TABLE 4. FIBRE COMPOSITION OF BARLEY STRAW AND WET BREWERS' GRAINS SILAGES (EXPERIMENT I AND II)

Treatments	NDF	ADF	Lignin	Si.	Cell.	HCell.
	(g/kg DM)					
			Experiment I			
I −0	834.8	564.5	95.9	17.5	49.86	27.03
I −2	711.8	442.3	97.3	23.0	34.50	26.25
I −3	668.6	406.3	88.3	19.5	31.80	26.23
I 4	616.2	372.9	83.4	17.1	28.95	24.33
I −5	602.3	356.5	86.9	12.4	26.96	24.58
Sig.[a)]	**	**	*	NS	**	*
			Experiment II			
II −0	779.8	521.5	98.5	19.9	42.30	25.83
II −1	650.0	383.4	80.2	18.5	30.32	26.66
II −2	611.4	324.4	71.5	12.4	25.29	28.70
II −3	576.1	313.3	74.6	19.2	23.87	26.28
II −4	542.9	290.3	67.7	14.9	22.26	25.26
Sig.[a)]	**	**	**	*	**	NS

Abbreviation: NDF = Neutral detergent fibre, ADF = Acid detergent fibre, Si. = Silica, Cell. = Cellulose, Hcell = Hemicellulose.

Cellulose = ADF − Lignin, Hemicellulose = NDF − ADF.

[a)] Significant difference: NS $p > 0.05$, * $p < 0.05$, ** $p < 0.01$.

agreement with the results reported by Woolford (1984) and McDonald et al. (1991) who suggested that the carbohydrate-rich materials such as molasses, sugars, starch from cereal meal or grains, whey, citrus pulp, and potatoes stimulate fermentation and result in an accelerated growth of lactic acid bacteria. Jones (1988) also observed that the incorporation of cereal into grass silages improved the fermentation quality without the need for addition of other chemical additives.

Nutritive value

The nutritive value of silage in both experiments was significantly ($p < 0.05$) improved by adding wet brewers' grains to silages based on barley straw. The crude protein content increased and all fibrous components decreased ($p < 0.01$) with increasing proportion of wet brewers' grains. Compared to the controls, the crude protein content of the silages mixed with wet brewers' grains increased from 93.2 to 171.2 (g/kg DM) in Exp. I and 126.6 to 214.7 (g/kg DM) in Exp. II. Correspondingly crude fibre content decreased from 202.6 to 118.9 (g/kg DM) in Exp. I and 253.0 to 166.7 (g/kg DM) in Exp. II (table 3 and 4). The results are in agreement with the findings of Jones (1988) who found a significant reduction in fibre content by barley addition and an increasing in silage dry matter content by cereal addition. The improvement nutritive value of mixed silages was associated with an improvement ($p < 0.01$) in *in vitro* dry matter digestibility as measured by both Abe and Horii and Tilley and Terry methods. The data show that increasing the proportion of wet brewers' grains increased the digestibility of the mixture barley straw silages (table 3). The results are supported by the findings of Krishna (1982) and Mandal et al. (1989), who reported that mixing and ensiling paddy straw and potato haulm (1:5 ratio) or wheat straw and poplar leaves (1:7 ratio) with 3% molasses, improved the fermentation quality and nutritive value of resulting silages, to the point where they met the maintenance requirements of cattle and rams.

Feeding trials were conducted to evaluate the apparent digestibility of semi field scale silages (Exp. III). These silages (table 5) were moderately preserved with a pH of 4.34 and 4.43, for F I and F II silages, respectively. They also had a considerably lower lactic acid concentration than that of the laboratory silages.

The F I and F II silages had a high crude protein content (153.5 and 163.0 g/kg DM) and a low crude fibre content (324.3 and 334.7 g/kg DM) as shown in table 6. The apparent digestibility of dry matter, organic matter and crude protein were moderate with F II were significantly ($p < 0.05$) higher than F I (table 7). The feeding studies showed that the silage made by mixing of barley straw, either dried or fresh, and wet brewers' grains supplied about 50% of their TDN and 10% of their DCP requirements.

TABLE 5. FERMENTATION QUALITY OF BARLEY STRAW AND WET BREWERS' GRAINS SILAGES USED FOR SHEEP FEEDING TRIAL (EXPERIMENT III)

Compositions	F I *	F II *
pH	4.3	4.4
Lactic acid (g/kg DM)	7.6	0.7
Acetic acid (g/kg DM)	18.0	12.9
Propionic acid (g/kg DM)	2.3	3.8
i-Butyric acid (g/kg DM)	0.1	0.2
n-Butyric acid (g/kg DM)	0.1	1.5
Ethanol (g/kg DM)	8.2	3.6

F I = Silage made from dried barley straw and wet brewers' grains.

F II = Silage made from fresh barley straw and wet brewers' grains.

* = The silages were mixed about 1:1 on a dry matter basis.

TABLE 6. CHEMICAL COMPOSITION OF BARLEY STRAW AND WET BREWERS' GRAINS SILAGES USED FOR SHEEP FEEDING TRIAL (EXPERIMENT III)

Compositions	F I *	F II *
Dry matter (g/kg)	342.7	229.3
Organic matter (g/kg DM)	951.3	935.6
Crude protein (g/kg DM)	123.4	163.0
Crude ash (g/kg DM)	48.7	64.4
Crude fat (g/kg DM)	76.8	72.3
Crude fibre (g/kg DM)	324.3	334.7
Nitrogen free extract (g/kg DM)	396.7	365.6

F I = Silage made from dried barley straw and wet brewers' grains.

F II = Silage made from fresh barley straw and wet brewers' grains.

* = The silages were mixed about 1:1 on a dry matter basis.

TABLE 7. APPARENT DIGESTIBILITY, TOTAL DIGESTIBLE NUTRIENT AND DIGESTIBLE CRUDE PROTEIN OF SILAGES DIET (EXPERIMENT II)

	F I*	F II*
Dry matter (%)	38.3±2.5[a]	47.2±2.4[b]
Organic matter (%)	40.8±2.6[a]	49.4±2.4[b]
Crude protein (%)	65.1±1.9[a]	70.7±1.6[b]
Crude fat (%)	83.2±2.0	83.4±1.7
Crude fibre (%)	35.5±4.4	34.6±3.4
Nitrogen free extract (%)	38.0±4.2[a]	33.1±2.6[b]
TDN (% DM)	50.0±3.9	51.3±2.7
DCP (% DM)	10.0±0.7	11.5±0.7

Abbreviation: TDN = Total digestible nutrient, DCP = Digestible crude protein.

F I = Silage made from dried barley straw and wet brewers' grains.

F II = Silage made from fresh barley straw and wet brewers' grains.

* = The silages were mixed about 1:1 on a dry matter basis

a,b Means in the same row with different superscripts differ significantly ($p < 0.05$).

It can be concluded that the fermentation quality and nutritive value of barley straw silage was considerably improved by mixing with wet brewers' grains.

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