Effects of Maturity at Harvest and Wilting Days on Quality of Round Baled Rye Silage

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ABSTRACT : A study was conducted to determine the effects of maturity at harvest and wilting days on the quality of round baled rye (*Secale cereale* L.) silage. This study was a 3×3 factorial arrangement in a split plot design with 3 replicates. The main plot was 3 harvesting dates at the stage of boot (20 Apr.), heading (29 Apr.) and flowering (14 May). The subplot was wilting day : 0 (unwilted), 0.5 and 1 day (0, 1, and 2 days at boot stage). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents of rye silage were significantly greater than those of rye before ensiling, but crude protein (CP) content and *in vitro* dry matter digestibility (IVDMD) were *vice versa*. Buffering capacity (BC) of rye harvested at flowering stage was decreased from 264 to 202 meq/kg at 1 day wilting, however, it was increased when harvested at boot or heading stage. The pH in wilted silage was the highest while that of flowering stage was the lowest. Water soluble carbohydrate (WSC) content of wilting rye was lower than that of unwilted, and the lowest at late harvesting stage. All plots had minimal WSC content for silage fermentation. Wilting treatment and delayed harvesting date caused an increase in dry matter (DM) content of round bale silage. The content of ammonia-N expressed as a portion of total N showed negative correlation with DM content. High quality silage according to ammonia-N content could be obtained from mid-harvest with wilting. There were highly significant differences in each organic acid between harvesting dates and wilting periods. Acetic and butyric acid contents were increased with delayed harvesting and prolonged wilting period, the lactic acid content, however, was decreased. This study demonstrated that harvest of rye from heading to flowering stage with wilting would be a recommendable method for making high quality rye silage using round bale system. *(Asian-Aust. J. Anim. Sci. 2001. Vol 14, No. 9 : 1233-1237)*

Key Words : Round Baled Silage, Rye, Harvest Stage, Wilting, Silage Quality

INTRODUCTION

Rye (*Secale cereale* L.) is an important forage crop for silage as well as hay in South Korea. In 1998, approximately 4,100 ton of forage rye seeds were imported into South Korea because rye is widely cultivated as the cool season component of double-cropping systems around the world (Williams et al., 1995). Harvesting of forage at an early heading stage of maturity optimizes both its agronomic yield and nutritional value for a lactating dairy cow.

Although silage is now the most common preserved cattle feed in many countries including South Korea, it is difficult to make good silage from grasses and crops due to high moisture content at harvest. Rye is also difficult to preserve as direct-cut silage due to the fact that its high moisture content may cause excessive fermentation during ensiling. Researchers (Marsh, 1979; Froetschel et al., 1991) indicate that wilting creates an ensiling environment that is conducive to a restricted fermentation, and the resulting silage is typically higher in pH and lower in fermented acids and NH_3-N concentrations. Adequate wilting of forage prior to ensiling, however, will enhance preservation and reduce the effluent that brings out nutrient loss and environmental contamination. It is known that *Clostridia* are more sensitive to moisture content in plant material than other aerobic bacteria. Therefore, DM concentration in fresh grasses should be higher than 350 g/kg to avoid spoilage in big bale silage (Jonsson et al., 1990). As wilting of plant was essential for some conservation systems, Agriculture Development and Advisory Service (ADAS, 1975) recommended a DM concentration of 250-300 g/kg for bunker silos and 350-450 g/kg for tower silos.

The most obvious change in the chemical composition of forage after harvesting is the reduction in water content because of wilting. Changes in the level of other chemical constituents are reduction in the content of non-structural carbohydrates due to hydrolysis and subsequent respiration of the released hexose sugar. The resultant production of CO_2 has been shown to account for much of the non-mechanical DM losses associated with wilting (Sullivan, 1973).

The wrapping of large round bales with stretch-wrap plastic films to make silage is an increasingly popular means of preserving forages as a relatively new method. In England, 5.3 Mt of big bale silage was made in 1993, and this amounted to 18% of the 28.6 Mt of total silage made (Haigh, 1995). The technology of round baled silage was introduced in the early 1990s in South Korea, but there is little technical information on the ensiling characteristics of round baled forage compared with other ensiling techniques. Consequently, the objective of this study was to determine the effects of maturity at harvest and wilting days on the quality of round baled rye silage.

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MATERIALS AND METHODS

Silage preparation

Forage rye was harvested at the boot, heading, and flowering stages with mower conditioner (SM 300) on 20 April, 29 April and 14 May in 1998, and wilting for 0, 0.5 and 1 day (0, 1 and 2 days at boot stage). It was raked following wilting. Baling (F21; Fort & Pegoraro Co. Italy; bale diameter×width : 1.2×1.2 m) began when the forage lay in the windrow. The bales were wrapped with a wrapper (F11, Fort & Pegoraro Co. Italy) using three layers of white stretch film manufactured by Integrated Packaging Reservoir Victoria Inc. (Australia). The bales were wrapped immediately after baling and stored outdoors in a single layer on their end.

Analytical procedures

Dry matter (DM) content of the rye and silages were determined by air force drying oven at 65℃ for 72 h. The dried samples were ground and kept for the analysis. Crude protein (CP) was determined by the Kjeldahl method (AOAC, 1995), NDF and ADF were measured by the method of Goering and Van Soest (1970), and IVDMD was determined by the method of Moore (1970), respectively.

A 10 g sample of each silage was macerated with 100 ml distilled water, filtered through a filter paper (#No. 6). The filtrate was used for the analysis of organic acid. The pH was measured with a pH meter (HI 9024; Hanna Instrument Inc. UK) after macerating a 10-g sample of silage in 100 ml of distilled water. Buffering capacity (BC) was analyzed as described according to Playne and McDonald (1966). NH_3-N was determined by Chaney and Marbach (1962) method. Organic acids were analyzed using gas chromatography (Model-3400; Varian Co., USA) and lactic acid was determined by the calorimetric method of Barker and Summerson (1941). Water soluble carbohydrate was evaluated by using the method of Deriaz (1961).

Data were analyzed using the General Linear Model (GLM) Procedure of SAS (1996). The statistical model was that appropriate for a 3×3 factorial arrangement in a split plot design with 3 replications.

RESULTS AND DISCUSSION

Forage composition

Table 1 shows the chemical composition of the rye at ensiling. Dry matter content of rye varied during harvest stage, ranging from 135 to 297 g/kg and was increased with progressed maturity at harvest ($p<0.001$) and prolonged wilting periods ($p<0.001$). However, BC of rye harvested at flowering stage showed different trends, and was decreased to 202 meq/kg at one-day wilting. Wilting reduced the WSC and IVDMD of the rye. Samples from boot stage had a high WSC concentration of 246 g/kg of the DM, but this had fallen to 139 g/kg at flowering stage. Haigh (1990) demonstrated that the WSC content of forage ensiled is often regarded as a useful indicator of forage quality for ensilage. Although a higher value of 30-35 g/kg of WSC content has been suggested, approximately 25-30 g/kg of WSC content in forage is desirable for silage making without additive. Crude protein was increased as wilting periods were prolonged. The result mentioned above was similar to that obtained by Fitzgerald (1996) in chopping silage. On the other hand, CP concentration was rapidly lowered from heading stage to flowering stage. As wilting time increased, the ADF and NDF concentrations of rye materials were increased. Progressed maturity at harvest also increased the concentrations of ADF and NDF. This agreed with the results of Brundage et al.(1979) that the highest ADF and NDF concentrations in oats were found at flowering stage. An interaction between harvest stage and wilting period was found in ADF concentration.

Silage composition

Table 2 shows some characteristics of the round baled rye silages. Wilting resulted in a significant increase in DM

Table 1. Chemical composition of rye materials prior to ensiling

Harvest stage	Boot			Heading			Flowering			Probability of		
Wilting period (day)	0	1	2	0	0.5	1	0	0.5	1	H	W	H×W
DM (g/kg)	135	207	264	178	235	418	297	346	553	***	***	***
BC (meq/kg)	280	284	294	239	241	254	264	249	202	***	***	***
WSC (g/kg, DM)	246	171	141	176	135	70	139	98	65	***	***	***
CP (g/kg)	180	205	224	163	181	175	76	77	80	***	**	*
ADF (g/kg)	258	260	288	333	344	359	338	349	374	***	***	NS
NDF (g/kg)	488	489	519	561	584	602	576	582	625	***	***	**
IVDMD (g/kg)	774	753	731	599	571	571	545	526	513	***	***	NS

H=Harvest stage, W=Wilting periods. * p<0.05, ** p<0.01, *** p<0.001, NS=Not significant.

Table 2. Chemical composition of round baled rye silage

Harvest stage	Boot			Heading			Flowering			Probability of		
Wilting period (day)	0	1	2	0	0.5	1	0	0.5	1	H	W	H×W
DM (g/kg)	140	182	204	184	228	425	244	328	561	***	***	***
pH	4.4	4.7	4.8	4.5	5.1	5.9	4.2	4.4	5.6	***	***	***
NH_3-N (g/kg, DM)	184	157	131	165	112	109	104	86	71	***	***	NS
CP (g/kg)	146	140	148	110	112	117	104	102	105	***	NS	NS
ADF (g/kg)	314	337	355	397	383	371	415	388	425	***	**	***
NDF (g/kg)	509	538	547	552	573	604	583	585	641	***	***	**
IVDMD (g/kg)	745	718	675	593	570	560	502	487	480	***	***	***

H=Harvest stage, W=Wilting periods. ** p<0.01, *** p<0.001, NS=Not significant.

Table 3. Organic acid composition of rye silage (% in DM)

Harvest stage	Boot			Heading			Flowering			Probability of		
Wilting period (day)	0	1	2	0	0.5	1	0	0.5	1	H	W	H×W
Lactic acid	5.48	6.32	6.72	6.49	7.36	7.88	7.72	8.04	7.08	***	**	**
Acetic acid	3.43	2.81	2.47	2.93	2.26	2.12	2.14	1.97	1.92	***	**	NS
Butyric acid	1.49	0.74	0.52	0.83	0.37	0.24	0.33	0.14	0.27	***	***	***
TOA	10.40	9.87	9.71	10.22	9.99	10.24	10.19	11.05	9.27	NS	NS	NS

TOA=Total organic acid, H=Harvest stage, W=Wilting periods. ** p<0.01, *** p<0.001, NS=Not significant.

concentration for rye silage (p<0.001) and harvest maturity also affected the DM concentration significantly (p<0.001). The pH of rye silage was the lowest at boot stage and the highest at heading stage. Wilting influenced the silage pH significantly and interaction between harvest maturity and wilting period was found (p<0.001). Crude protein concentration of rye silage was decreased with delayed harvest stage (p<0.001), but there was no statistical difference in CP concentration among various wilting periods. The concentrations of ADF and NDF in rye silage were increased as harvest maturity progressed (p<0.001). Wilting also showed significant differences in ADF and NDF concentration, but did not have a general trend. There was a significant difference in IVDMD among harvest maturity and wilting period applied (p<0.001). The value of IVDMD in rye silage was lower than that of rye before ensiling. Gordon (1981) reported that wilting would decrease the IVDMD of herbage.

Volatile fatty acids (acetic and butyric acid) and ammonia-N expressed as proportion to total N were high in the non-wilted silage (table 2). Butyric acid and ammonia-N concentration were considerably lowered in the wilted silage which indicates a better pattern of fermentation. An ammonia-N value of less than 80-100 g (kg of total N) is commonly used to represent well fermented silage (Haigh and Hopkins, 1977). Using this criterion, harvest after heading stage with wilting would produce well-fermented silage, as indicated by the present study.

Organic acid composition

Organic acid composition of rye silages is presented in table 3. Lactic acid concentration of all wilted silage was greater than that of non-wilted silage (p<0.001) except when the silage was made at flowering stage. A higher lactic acid concentration in wilted silage compared with non-wilted is unusual though similar results were found by Castle and Watson (1970; 1982). High lactic acid concentrations show the increased efficiency with which WSC is converted to acid and requires to be interpreted in relation to total acid concentrations (Haigh and Parker, 1985). If more than 50% of fermentation acids in silage are present as lactic acid, fermentation can be judged as satisfactory (Parker and Bastiman, 1982). The effect of wilting on lactic acid concentration was less consistent, although there was a trend toward decreasing lactic acid concentration in silage as DM concentration increased due to wilting (Marsh, 1979).

Acetic acid concentration was decreased by delayed harvest and wilting (p<0.001), but an interaction between harvest stage and wilting period was not found. Enterobacteria and heterofermentative LAB (lactic acid bacteria) produce acetic acid which is a much weaker acid than lactic acid and increases the loss of DM. Additionally, high levels of acetic acid can reduce silage DM intake in beef and dairy cattle. In this experiment, acetic acid concentrations were above 2% from boot to heading stage, but were below 2% harvested at flowering stage with wilting.

Table 4. Correlation coefficient (r) between quality parameters for round baled rye silage

Quality parameter	Buffering capacity	pH	NH_3-N	Acetic acid	Butyric acid	Lactic acid
Dry matter	-0.72**	0.73**	-0.74**	-0.62**	-0.35	0.48*
Buffering capacity		-0.44*	0.56**	0.39*	0.38*	-0.14
pH			-0.59**	-0.58**	-0.29	0.69**
NH_3-N				0.78**	0.68**	-0.49**
Acetic acid					0.58**	-0.62**
Butyric acid						-0.51**

*, **=Significant at the p=0.05 and p=0.01 probability levels, respectively.

Butyric acid concentrations in wilted silage were significantly less than in non-wilted and decreased with delayed harvest stage ($p<0.001$). Butyric acid production generally indicates clostridial activity. It can be divided into two groups : one that ferments sugar and organic acid like lactic, and the other ferments amino acids. Both groups affect silage quality negatively and *Clostridia* is sensitive to low pH. This sensitivity is dependent upon the moisture content of the forage. The higher moisture content in the crop, the lower the critical pH required to stop clostridial growth. Muck and Bolsen (1991) reported that clostridial activity is rare in a crop ensiled with less than 65% moisture due to the fact that there are usually sufficient sugars to reduce pH to the point at which *clostridia* will not grow. A value of less than 5-10 g/kg DM is required for good-medium quality silage (Brierem and Ulvesli, 1960). According to this criterion, all wilted rye produced well-fermented silage while non-wilted silage harvested at boot stage was poorly fermented.

Correlation between quality parameter

Correlation coefficients (r) between quality parameters for rye silage is shown in table 4. Dry matter content was highly correlated ($p<0.01$) with buffering capacity (-0.72), pH (0.73), and ammonia-N concentration (-0.74). This is in accordance with the statement of Williams et al. (1995) that wilting of high moisture forage prior to ensiling usually enhances preservation and creates an ensiling environment that is conducive to a restricted fermentation, and the resulting silage is typically higher in pH and lower in ammonia-N concentration. Buffering capacity was highly correlated with ammonia-N concentration (0.56), and pH was highly correlated with ammonia-N (-0.59), acetic (-0.58) and lactic acid concentration (0.69). Ammonia-N concentration was correlated with acetic acid (0.78), butyric acid (0.68), and lactic acid (-0.49). Kim et al. (1999) demonstrated that ammonia-N was highly correlated with acetic acid (0.80), butyric acid (0.82), and lactic acid (-0.75) in inoculant treated rye silages.

The present study showed that the harvest after heading stage with wilting for 0.5-1 day was the best treatment for enhancing subsequent preservation of rye as round baled silage.

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