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Research Article

Effect of Tedding Time and Frequency on the Feed Value and Drying Rate of Rye(*Secale cereale* L.) Hay

Yu Wei Li[1,2], Guo Qiang Zhao[2], Chang Liu[1], Sheng Nan Wei[1], Hak Jin Kim[2] and Jong Geun Kim[1,2,*]

[1]Graduate School of International Agricultural Technology, SNU, Pyeongchang, 25354, Korea

[2]Research Institute of Eco-friendly Livestock Science, GBST, SNU, Pyeongchang, 25354, Korea

ABSTRACT

Hay-making is one of the most common way for forage preservation in livestock industry. The quality and production of hay could be affected by various factors. This experiment was conducted to investigate the effect of tedding time and frequency on drying rate and feed value of forage rye (*Secale cereale* L.) hay. Rye was harvested on heading stage using mower conditioner. Hay was tedded at each set hour(09:00, 13:00 and 17:00) and sampled at each set hour to determine dry matter (DM) content. After two months' preservation, CP (crude protein), ADF (acid detergent fiber), NDF (neutral detergent fiber), IVDMD (*in vitro* dry matter digestibility), TDN (total digestible nutrient), RFV (relative feed value), DM loss, visual scores and total fungi count were determined for estimation of hay quality. Tedding was necessary for both speeding up drying rate and improving forage quality. Tedding at 17:00 showed lower NDF content ($p<0.05$), and also higher RFV value was found compared with tedding at 9:00 and 13:00 ($p<0.05$). On the other hand, it was observed that more DM losses would be found when tedding later ($p<0.05$). Tedding in 1~3 times per day were lower in ADF and NDF content ($p<0.05$), increased CP, TDN and RFV ($p<0.05$), got less DM loss ($p<0.05$), and contained less fungi during conservation compared with no tedding ($p<0.05$). On the other hand, tedding too frequent caused more DM loss ($p<0.05$). In conclusion, for shorter drying process and higher quality of forage rye hay, tedding at 13:00～17:00 for 1～2 times per day was recommended in this study.

(**Key words**: Tedding frequency, Tedding time, Drying rate, Hay quality, Fungi)

Ⅰ. INTRODUCTION

In livestock industry, forages provide the main necessary nutrients in the ruminant diets and is vital for the acquisition of digestion physiology of rumen. There are two options for processing of forage that ensiling and hay-making due to the farms' requirements and the local meteorological condition.

Haymaking is accomplished through rapid removal of moisture in plant to reach DM concentration above 800 g kg^{-1} which is the dry matter (DM) level for long-term hay storage without further nutrient loss. Dry matter and nutrient contents could be lost during harvesting, drying and preservation due to chemical, physical, and biological reactions. Optimized hay production management is important to achieve consistent production of high quality hay. There are three operations used in haymaking to manipulate the swath: tedding, swath inversion and raking (Rotz et al., 1983). Tedding is a useful way to speed up the drying rate by moving the bottom part to upper surface. Tedding requires mechanical energy and labors. So, farmers should choose the optimum tedding methods considering the efficiency of tedding cost. It has been shown that tedding increased drying rate of hay and bruising the herbage also did so (Murdoch et al., 1963). Due to chemical nutritive value of leaves is higher than stem, tedding losses showed more proportion of leaves than stem (Savoie, 1987). But tedding also causes many loss of DM. The loss caused during tedding process is proved between 1~3%, and can be more under improper management (Murdoch et al., 1963; Savoie, 1982). And legume showed more loss than grass because of the drop of leaves (Savoie et al., 1987).

In order to lose the moisture of bottom part faster and dry entire plant more evenly, adding frequency of tedding is an efficient method to achieve the target. Many experiments showed that tedding frequency could speed up drying rate (Dirk and John, 2015). On the other hand, it was proved that tedding too frequently will cause a nutrient loss from the

*Corresponding author: Jong Geun Kim, Graduate School of International Agricultural Technology, Seoul National University, Pyeongchang 25354, Korea. Tel: +82-33-339-5728, Fax: +82-33-339-5727, E-mail: forage@snu.ac.kr

Persian clover. The content of CP (crude protein) decreased as tedding frequency increased. ADF (acid detergent fiber) and NDF (neutral detergent fiber) of tedding 3 times are higher than 1 or 2 times (Kim et al., 2004). So, it is very necessary to master which tedding frequency is optimum to manage hay making. In another experiment, drying rate of Italian ryegrass had been affected by tedding frequency with 3 days after it was cut. Tedding frequency showed no influence on ADF and NDF, but effected CP and RFV (relative feed value) (Park et al., 2013).

So, this experiment investigated the drying rate and quality of rye (*Secale cereale* L.) hay in relation to tedding time and frequency during drying process in Pyeongchang, South Korea.

Ⅱ. MATERIALS AND METHODS

1. Experimental site and materials

These experiments were conducted in experimental field of Pyeongchang Campus, Seoul National University, Republic of Korea. The experiment field located in mountainous areas, averages about 600~700 meters above sea level. It has a humid continental climate, with four different seasons, spring is warm and humid, besides the winter is cold and long. During these experiments (5 May~9 May), the average temperature was 13.4 ℃, average amount of precipitation was 4.8mm, average wind speed was 4.7m/s, and the average humidity was 66.1% (source from Korea Meteorological Administration). The comparison of average air temperature and precipitation during the experimental period and normal years was showed in Fig. 1.

Rye (*Secale cereale* L.) is a grass grown extensively as a grain, a cover crop and a forage crop all over the world. In the current study, rye was utilized as the experimental material, which was planted on 25 September in 2015 and harvested at heading stage on 5 May in 2016 with mower conditioner. Other detail information of samples are showed in Table 1.

2. Hay making and evaluation

Experimental fields were established in a homogeneous area within a fenced area at total of six 10 m^2(5 m x 2 m) quadrat. The quadrats were separated from each other by 1 m strips. Different treatments were randomly applied to the quadrats.

In this experiment, three different treatments of tedding time were applied: tedding at 09:00 in the morning, 13:00 and 17:00 in the afternoon every day. At the same time, hay samples were taken regularly three times (9:00, 13:00 and 17:00) before

Table 1. Agronomic characteristics of rye used in this experiment

Growth stage	Heading date	Dry matter (%)	Plant height(cm)	Yield (kg/ha)	
				Fresh matter	Dry matter
Heading stage	27 April	18.8	111	27,833	5,233

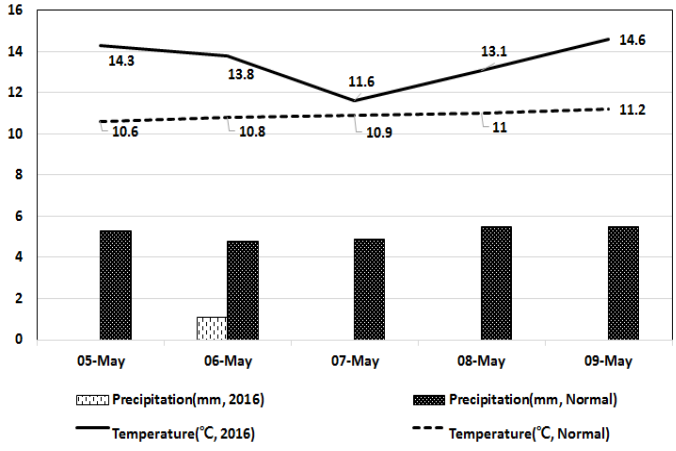


Fig. 1. Comparison of average air temperature and precipitation during the experimental period and normal years

tedding every day for the determination of moisture content.

For the tedding frequency, four treatments were applied in this study: tedding only one time, two times, three times and without tedding. Also, hay was sampled regularly three times (9:00, 13:00 and 17:00) before tedding every day to determine the moisture content.

After two months' storage, the baled hay were opened to evaluate the visual score (according to leafiness, odor, color, softness and mold). Visual score was estimated by the criterion described by Burns and Gary (1991). Dry matter (DM) loss of hay during storage was calculated according to the weight and DM content of hay before and after two months' storage.

The spread-plate method was used for viable counting of fungi (Michael et al., 2012). Dilution was prepared by homogenizing 1g of samples with 9ml sterile physiological saline (0.85% NaCl solution). Then the extract samples were pipetted onto the surface of a PDA (Potato Dextrose Agar) plate and spread evenly over surface of agar using one-off plastic spreader. After 3 days of incubation at 25℃, the agar plates were checked for fungal population.

3. Chemical analysis

300 g of each samples were collected and dried in 65 ℃ air-forced drying oven for 72 hours for determination of dry matter (DM) content. Subsequently, the dried samples were milled through a Wiley mill with 1 mm screen (Thomas Scientific, Inc., New Jersey, USA) and then stored in plastic bottles with screw tops prior to analysis.

Crude protein (CP) content was determined using Dumas method (Jean-Baptiste Dumas, 1884). The Italy machine "Automatic Elemental Analyzer Euro Vector EA 3000" (EVISA Co., Ltd, Milan, Italy) was utilized.

Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined using the ground sample by the method of Goering and Van Soest (1970). Machine "ANKONM 2000 Automated Fiber Analyzer" (Ankom Technologies, Inc., Fairport, NY, USA) from America was used.

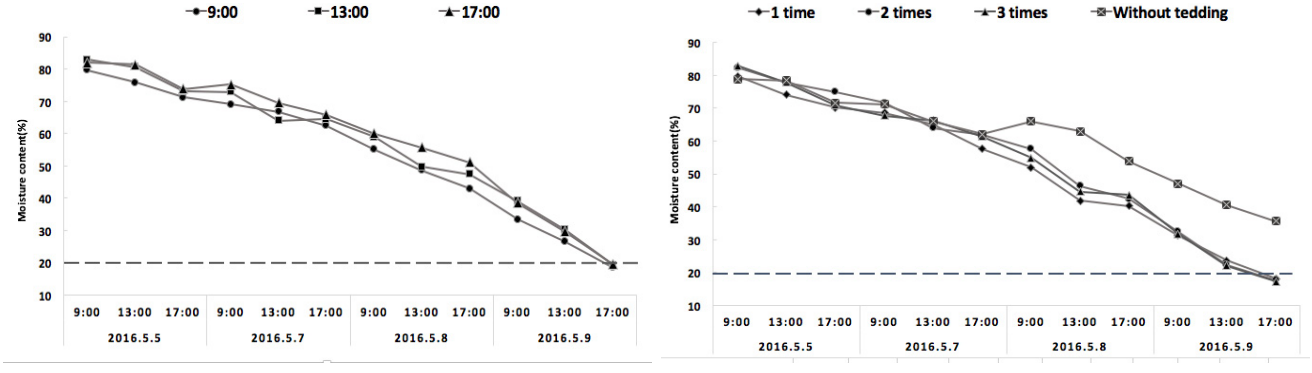
The two-stage technique (Tilley and Terry, 1963) was used for determining *in vitro* dry matter digestibility (IVDMD) by Daisy Incubator (Ankom Technologies, Inc., Fairport, NY, USA). 0.5~0.6 g ground sample was incubated in rumen fluid for a period of 72 hours and then followed by the NDF procedure.

4. Statistical analysis

The general linear model (GLM) procedure of SAS (2002) was used for statistical analyses. A probability level of the least significant difference (LSD) test ($p<0.05$) was considered to be statistically significant.

Ⅲ. RESULTS AND DISCUSSIONS

The result showed that the field drying rate of rye hay was the highest when tedding at 9:00 (Fig. 2). Tedding at 9:00 and 13:00 were more effective on speeding up the drying rate compared with tedding at 17:00. But the difference was not so obvious. In addition, it was proved that both temperature and humidity could affect respiration of grass samples (Parkes and Greig, 1974).



(a) (b)

Fig. 2. Effect of tedding methods on the drying rate of rye hay (a: tedding times, b: tedding frequency)

Table 2. Effect of tedding times on the forage quality of rye hay

Tedding time	CP	ADF	NDF	IVDMD	TDN	RFV
	---------- % in DM----------					
Herbage	8.2	36.1	58.8	73.6	60.4	96
09:00	9.0	36.0	59.6	714	60.5	95
13:00	9.2	35.4	59.1	71.2	61.0	97
17:00	9.5	35.0	58.6	72.5	61.3	98
Mean	9.2	35.5	59.1	71.7	60.9	97
LSD(0.05)	NS	NS	1.04	NS	NS	3.38

* NS: non-significant

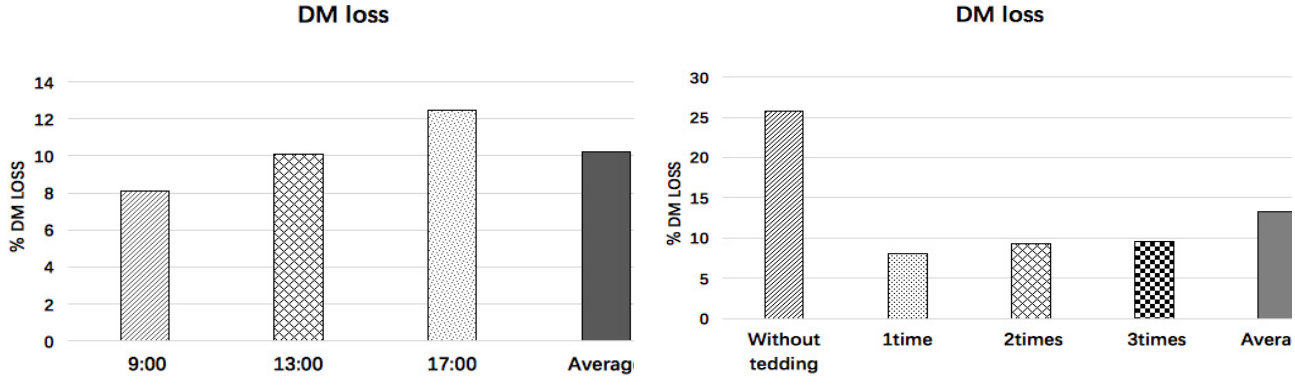
* CP: crude protein, ADF: acid detergent fiber, NDF: neutral detergent fiber, IVDMD: *in vitro* dry matter digestibility, TDN: total digestible nutrient, RFV: relative feed value

Tedding at 9:00, 13:00 and 17:00 all achieved a moisture content less than 20% in four days which were showed as 18.4%, 19.2% and 19.4%, respectively. Although drying rate of rye hay had been affected by tedding time within three days after it was cut, the three treatments arrived MC equal to 20% at almost the same time. The similar result of Italian ryegrass hay was proved by Park et al. (2013) that tedding was ineffective after 3 days. Impeller and roller samples of tall fescue arrived moisture content under 20% in 2-3 days at 13:00 (Kim et al., 2016).

As for tedding frequency, the field drying rate of rye hay was the highest when tedding 3 times per day. All of tedding 1, 2 and 3 times per day achieved a moisture content below 20% in four days as 18.2%, 17.8%, and 17.3% respectively as is shown in Fig. 2. However, group without tedding did not reach the MC below 20% on the fourth day. Although tedding frequency could speed up drying process, drying rate of rye hay just was affected within three days after it was cut. The same result was proved that drying rate of Italian ryegrass also had been affected by tedding frequency within 3 days after it was cut (Park et al., 2013). Similar result also showed that tedding 3 times per day speed up the drying rate of oat hay compared with tedding 1 time per day (Han and Kim, 1996). But another experiment on clovers made by Kim et al. (2004) said that tedding frequency did not show a significant effect on hay drying performance, and the frequency of tedding caused higher yield loss.

Tedding at 17:00 showed lower NDF content (p<0.05), and had higher level of RFV compared with tedding at 9:00 and 13:00 (p<0.05) (Table 2). But there was no significant difference found among the three treatments on content of CP, ADF, IVDMD and TDN (p>0.05) (Table 2).

Respiration would transfer DM to heat, and the heat also could reduce the digestibility of CP though the formation of ADIN (Thomas et al., 1982). On the other hand, it was observed that the latter tedding (17:00) caused more DM loss (p<0.05) (Fig. 3). It has been proved that the loss from tedding was 1~



(a) (b)

Fig. 3. Effect of tedding methods on the DM loss of rye hay (a: tedding times, b: tedding frequency)

Table 3. Effect of tedding frequency on the forage quality of rye hay

Tedding frequency	CP	ADF	NDF	IVDMD	TDN	RFV
	---------- % in DM----------					
Herbage	8.2	36.1	58.8	73.6	60.4	96
1 time	7.6	35.8	59.3	70.0	60.7	96
2 times	8.3	37.2	60.5	70.8	59.6	92
3 times	7.2	36.3	60.0	71.3	60.2	94
Without	7.5	37.7	61.8	68.8	59.1	89
Mean	7.7	36.8	59.5	70.2	59.9	93
LSD(0.05)	NS	1.19	2.04	NS	0.94	3.96

* NS: non-significant

* CP: crude protein, ADF: acid detergent fiber, NDF: neutral detergent fiber, IVDMD: *in vitro* dry matter digestibility, TDN: total digestible nutrient, RFV: relative feed value

Table 4. Effect of tedding methods on the visual score of rye hay after preservation

Tedding time	Stage of harvest	Leafiness	Color	Odor	Softness	Mold	Total*
9:00	30	21	11	14	8	-4	80
13:00	30	23	11	13	8	-3	82
17:00	30	24	12	14	8	-3	85
Mean	30	23	11	14	8	-3	83
Tedding freauency							
1 time	30	26	11	13	8	-4	84
2 times	30	25	10	14	8	-3	85
3 times	30	20	8	14	8	-2	78
Without	30	26	6	7	5	-10	64
Mean	30	24	9	12	7	-5	78

*: > 90: Excellent; 80-90: Good; 65-79: Fair; < 65 Poor.

3% of the whole crop yield, and the loss could be more during real process (Ciotti, 1979). The respiration would transfer DM to heat, caused more losses as well (Rotz, 1988). Laboratory estimation indicated that the yield losses of dry legumes could exceed 20% due to tedding (Savoie, 1987).

In this experiment, tedding at 9:00, 13:00 and 17:00 didn't showed marked difference on viable count of total fungi after preservation (p>0.05) (Table 4). Tedding showed significant influence on the quality of rye hay. Across the result, samples tedded over 1 time were lower in ADF and NDF content (p<0.05), but higher in TDN and RFV level (p<0.05) (Table 2), showing an obvious improvement on decreasing DM loss (p<0.05) (Fig. 3), and contained less fungi during conservation compared with the group of treatment without tedding (p<0.05) (Table 4).

It may as a result of the quadrat without tedding didn't arrive the MC below 20% before baling, the moisture increased the heat of hay bales during preservation, causing ideal environment for fungi growth. The amount of mold and yeast increased with increasing preservative duration and temperatures (Wang et al., 2014). But as for percentage of CP and IVDMD, there is no obvious difference been discovered within the four treatments (p>0.05). On the other hand, there is no significant difference when tedding within three times. Results in other papers showed that tedding frequency had no effect on ADF and NDF content, but affected CP and RFV of alfalfa hay (Park et al., 2013). Experiment on clovers hay made by Kim et al. (2004) said that ADF and NDF contents of three times were higher compared with tedding 1~2 times. And tedding 2 times was recommended for higher quality of annual legume hay. But there was another experiment on tall fescue showed different result that tedding frequency did not affect the

Table 5. Effect of tedding time and frequency on the viable count of fungi in rye hay after preservation

Tedding time	Microbial count of fungi (CFU/g)	Tedding frequency	Microbial count of fungi (CFU/g)
9:00	6.7×10^7	1 time	2.4×10^6
13:00	4.8×10^7	2 times	6.1×10^6
		3 times	5.6×10^6
17:00	4.3×10^7	Without	4.2×10^7
Mean	5.1×10^7	Mean	1.4×10^7
LSD(0.05)	NS	LSD(0.05)	1.96×10^6

* NS: non-significant

content of ADF, NDF, RFV and CP significantly (Kim et al., 2016). The influence of tedding frequency also depends on species. Tama ryegrass was showed less affected by tedding frequency compared with other legumes (Taylor et al., 1979).

Visual scores of all treatments fell in the level of good (80, 82 and 85). Although they were all good, tedding at 17:00 got higher score than others. Because it contained higher leaf proportion, and delighter odor (Table 3). Han and Kim (1996) proved that the species with high moisture content got lower visual scores, easily showed dark color and contained more fungi and mold during preservation. Visual scores of tedding only 1 time and 2 times per day were good (84 and 85), but tedding 3 times per day showed fair (78) and the group without tedding showed in poor (64) (Table 3). The reason that tedding 3 times got less score than 1 and 2 times was it had less leaf proportion and yellow color. Too frequent tedding lost more leaves, thus causing higher DM loss.

Ⅳ. CONCLUSION

First of all, tedding is necessary for both speeding up drying rate and improving quality. Tedding at 17:00 showed lower in NDF content and had higher level of RFV compared with tedding at 9:00 and 13:00 ($p<0.05$). But, it was observed that latter tedding cased more DM loss ($p<0.05$). As overall consideration, tedding in afternoon but not too late is the optimum tedding time.

Tedding 1~3 times per day had better quality and speed up drying rate obviously compared with no tedding. Tedding over 1 time was lower in ADF and NDF content ($p<0.05$), higher in CP, TDN and RFV score ($p<0.05$), showing an obvious improvement on decreasing DM loss ($p<0.05$), and contained less fungi during conservation ($p<0.05$). On the other hand, tedding frequently caused more DM loss in management due to the material damage loss during drying and baling process. For getting better rye hay, reducing time, labor and financial investment in the meantime, this research recommends 1~2 times tedding per day.

The rye hay bales with high moisture got lower visual score after preservation. It showed in dark even black color, smells of mildew, rotten or mustiness, prone to brittle low quality hay. On the other hand, too frequent tedding also could have lower visual score due to less leaf proportion causing more DM loss.

Ⅴ. ACKNOWLEDGEMENT

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