Master's Thesis of Science in Agriculture

Effect of Different Practical Methods on the Quality and Drying Rate of Rye (*Secale cereale* L.) Hay

제조방법이 호밀 (*Secale cereale* L.) 건초의 품질 및 건조율에 미치는 영향

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Abstract

Due to seasonal growth of grass and unfavorable weather, is necessary to preserve the forage for continuous supply. Hay making is one of the popular methods to feed livestock. Choosing an optimum management to improve quality of hay would be valuable to hay producer. Rye (*Secale cereale* L.) hay samples were collected after harvesting in heading stage from experiment field in Pyeongchang Campus of Seoul National University to investigate the drying rate and quality in relation to chemical conditioning, tedding time, tedding frequency and cutting height. Chemical conditioning, K_2CO_3 could speed up drying rate, increase IVDMD ($p<0.05$), decrease DM loss ($p<0.05$), and contain less fungi during conservation ($p<0.05$). While Na_2CO_3 showed ineffective on neither drying rate nor quality compared with no chemical conditioning ($p>0.05$). Tedding is necessary for both speeding up drying rate and improving forage quality. Tedding at 17:00 showed lower in NDF content ($p<0.05$), and had higher level of RFV compared with tedding at 9:00 and 13:00 ($p<0.05$). On the other hand, it was observed that more DM will be lost when tedding latter ($p<0.05$). 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 ($p<0.05$). Cutting in longer height (15cm) of rye could speed up the drying rate, and showed higher in CP content ($p<0.05$). But cutting in 15cm or 8cm didn't show significant difference in ADF, NDF, IVDMD, TDN and RFV ($p>0.05$). This experiment recommends pretreating with K_2CO_3 before harvesting, then cutting in 8cm at heading stage. During drying process tedding at 13:00 ~ 17:00 for 1 ~ 2 times per day is the most optimum method to speed up drying process and get higher quality hay.

Keywords: tedding frequency, tedding time, chemical conditioning, cutting height, drying rate

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List of abbreviations

ADF– Acid detergent fiber

NDF– Neutral detergent fiber

CP– Crude protein

IVDMD– *In vitro* dry matter disappearance

TDN– Total digestible nutrient

RFV– Relative feed value

DM– Dry matter

MC– Moisture content

TMR– Total mixed ration

CF– Crude fiber

DDM– Digestible dry matter

DMI– Dry matter intake

SAS– Statistical analysis software

1. Introduction

1.1 Study Background

During the plant growing season, fresh forage is the best fodder. But cold winter would not permit the growth of plant. It makes utilization of forage out of balance (summer and autumn excess while winter and spring are insufficient). To solve this problem and ensure the long term supply of high quality fodder, haymaking becomes one of the popular methods of forage for feeding livestock.

Hay can supply most part of nutrients. On the other hand, haymaking suffers loss of dry matter due to plant respiration, mechanical damage and weather conditions. The goal of haymaking is maintaining the dry matter and nutrition of forage. Besides, drying rate is very important to haymaking to minimize the DM losses. So, rapid removal of internal moisture from plants to achieve a target moisture content below 20% is a crucial phase of haymaking. Plant respiration is a natural stage that plant dose not die and continues respiring after being cut until the moisture content drop down below 40%. Respiration decreases the quality of hay by removing the digestible nutrients (Rotz and Muck 1988). During field drying phase, soluble carbohydrates and sugar stored in plant will be consumed primarily causing losses of yield and quality, while content of CP, ADF, NDF, and lignin will not be affected by respiration increase (Rotz and Muck. 1988). And respiration does cause a low level of nutrition and DM during preservation (Wilkenson and Hall, 1966).

Weather conditions remain the most restricting factor in drying process. Rainfall would prolong the duration of plant respiration, increase microbial activity and leach the soluble carbohydrates, protein, and certain minerals out of plant. Due to these processes, rainfall can cause a lot of losses. Especially during field curing phase, the yield and quality can be affected a lot by rainfall (Rote and Abrams, 1988). In the influence of weather, solar radiation level is crucial, since sun energy is required to move and evaporate moisture out of forage. On another hand, ventilation is very important to speed up the dry rate. And the wind is the most efficient tool to get better ventilation. Experiment made by Zhang (2015) proved that air blower speeded up the drying phase effectively.

Hay is normally baled at a moisture below 20% when the forage is stable for long-term storage that maybe a year, and perhaps longer. But because of chemical, physical and biological process during harvest, drying and preserve phases cause DM and nutrition losses. Good management and proper equipment are important to consistently produce high quality hay.

1.2 Aims of research

Due to frequent rainfall in South Korea, silage is more popular method of forage preservation. However, silage can’t be consumed and the quality can’t be check before silage stable state. Therefore, the hay used to instead of silage is import from other countries. This experiment aimed to help increasing domestic hay production in South Korea.

For purpose of rapid removal of internal moisture from plants to achieve target moisture content below 20% as soon as possible, mastering knowledge of proper practical methods is essential for making high quality hay and saving the cost of each process. This experiment investigates the drying rate and quality of rye (*Secale cereale* L.) hay in relation to cutting height, chemical conditioning, tedding time and tedding frequency.

2. Literature review

2.1 Selection of crop for hay

Hay quality depends on farm' s choice. They decide the species of cultivating crop in their field. Some species are best for hay while others are best for pasture. Farmers who want to make high quality of hay must choose species and varieties of crop that will match their needs. Once species are selected, whether for pure or mixed stands, farmers can work for their particular growing conditions, soil type, disease and management. Good hay comes from high quality of raw materials cultivated the best conditions of field. It has been proved that legumes have higher nutrition levels than most of grasses, and cool-season grasses have higher CP concentration, less fiber than warm-season grasses when they are at the same stage of maturity (Dirk and John, 2015). Orchardgrass bales were easier to significant molding and lost more quality at the same moisture content as alfalfa (Krishona. 2011). And different crops showed different acceptability of rainfall. It was be showed that rainfall caused more loss of alfalfa alone than alfalfa-grass mixture (Collins, 1985).

2.2 Harvest of hay

2.2.1 Cutting height

Cutting height affected regrowth and productivity, dry matter and nutrition yields are higher in shorter cutting height (Sheaffer *et al.,* 1988). The same result from Smith and Nelson (1967), Kust and Smith (1961) also said that cutting in shorter height showed higher yield. Low cutting height showed higher dry matter yield during the first year. However, total yield and regrowth were lower in the second year (Bolormaa, 2008). Shorter cutting heights increase the yield of field, but lead to more soil being picked up resulting in poor quality and high ash contained forage. Quality of alfalfa decreased when cutting in shorter height and RFV (Relative Feed Value) rose from 0.9 to 7 units per inch with the increase of cutting height (Daniel *et al.,* 2007). Leaves are higher in relative feed value (RFV) and stems typically contain higher levels of non−digestible nutrients. So, nutritive value of stems is lower than leaves (Santis *et al.,* 2004). It is proved by them that the nutritive value, IVDMD and CP declined with the reduction in leaf stem ratio (LSR). But Dirk and John (2015) proved the influence of cutting height also depended on the species, because the carbohydrate reserves are located in different parts of plant. Forage preserving their growth value underground is less affected by cutting height and can be harvested shortly. Other species that store their regrowth reserves in stem will have low nutrition stand if being cut too close. Cutting frequency showed more influence than cutting height but cutting lower occurred stand damage (Smith. 1972). The similar result proved by Daniel (2007) said cutting height affected more when cutting more times. Tall height was need to supply the nutrition for regrowth. Higher cutting height increased stubble C / N supply to regrowth shoots, then improve alfalfa winter survival and persistence, as well as spring regrowth (Meuriot *et al.*, 2005). And it also be discovered that crown buds are more productive than stem buds, cutting height could stimulate the development of crown bud. (Ottman and Rogers. 2000.)

2.2.2 Cutting time

Cutting time is very important for forage quality, quantity and regrowth. Deciding the best time to harvest involves considering factors such as weather, the species or species mixture, the intended use and the maturity of the forage. Forage maturity is proved to be the most effective factor compared with other single element (Dirk and John, 2015). It shows the greatest nutritive value when all leaves are fully developed and seed or flower heads are just a bit short of full maturity. Cutting too early can't be cured easily due to high moisture content, and it will produce a lower yield (Don Ball *et al.,* 2001). The quality of small grain crops depended on the stage of maturation, and declined with plant maturity (Carol *et al.*, 2004). The quality of hay harvested at late boot and heading stage was much better than harvested at bloom stage (Seo *et al.*, 2000). And it was proved that timothy in mature stage dried faster than immature (Savoie and Beauregard. 1974). There is usually about a two-week "window" of time in which hay is at its ideal stage for harvesting forage.

2.2.3 Cutting frequency

It was discovered that total yield of field decreased as the frequency of cutting increased (Bolormaa, 2008). It showed that alfalfa cut four times per year yielded 7% more than harvested five times, and 28% more than harvested six times (Kallenbach *et al.,* 2002). Harvesting three times per year without fertilization was proved to be the most suitable practice for mountain hay meadow (Olívio *et al.*, 2009).

2.3 Conditioning of hay

Treatments used to reduce the forage's resistant to moisture loss are commonly known as conditioning. There are many types of conditionings such as mechanical, chemical, and other techniques. The effectiveness of a conditioning treatment is greatly influenced by plant, swath, and land conditions. Park (2013) reported that it needs for 3 or 4 days to make Italian ryegrass hay with conditioning and tedding in Korea.

2.3.1 Mechanical conditioning

Mechanical conditioning crushing, breaking and abrading the forage material is widely used by forage producers. It uses either rolls or impellers to condition the forage (Rotz *et al.*, 1987). The first phase of drying is moisture loss from the leaves through the stoma. The initial moisture loss is not affected by conditioning. The second drying is bring out in leaf and stem. At this phase conditioning can help increase drying rate. The final phase of drying is the loss of more tightly held moisture, particularly from the stems (Dan, 2003). The rolls can crush the stem and expose the interior for much more rapid drying (Rotz *et al.*, 1987). Mechanical conditioning shortened 1.5−1 day of field drying compared with chemical conditioning, and 1−2 days compared with no conditioning. And mechanical conditioning showed higher visual score, ADF, NDF, IVDMD and RFV (Seo *et al.*, 2000).

2.3.2 Chemical conditioning

Using of drying agents is another technique used in some area, to hasten the moisture loss from crop. The agent is sprayed onto the crop at cutting and affects the waxy cutin or outer layer of the crop stems allowing the movement of water through the stems and leaves (Dan, 2003). Chemical conditioning can improve drying by opening stoma desiccating the plant prior to cutting, or by modifying the waxy surface of the plant. At the present, potassium carbonate (K_2CO_3) and Sodium carbonate (Na_2CO_3) are used for common practical chemical treatments. This treatment is effective on legume species and grass-legume mixes, but has no effect on grass species alone (Seo *et al.*, 2000). Chemical conditioning shows no effect on speeding up drying rate but improves *in vitro* digestibility of alfalfa (Shan *et al.*, 2006). And another experiment also showed that chemically conditioned hay had higher crude protein content than untreated hay when both were dried under relatively good drying conditions (Ehle *et al.*, 1985). On the other hand, chemically conditioned hay showed similar quality as untreated hay (Johnson *et al.*, 1983). Rotz (1987) proved that the influence of chemical conditioning depends on cutting frequency. Chemical conditioning alone is most effective on second and third cuttings, less effective during first cutting. Because greater crop yields during first cutting creates thicker swaths. Conditioning can't enhance the drying rate of cool-season grasses, because the leaf sheath prevents chemical conditioning from contacting their stem directly (Dirk and John, 2015).

2.4 Tedding

When forage dries in the field, the top part exposing to air and sunlight dries more rapidly compared with the shaded bottom part lying to the moist soil. Swath manipulation can also improve drying rate by spreading the hay over more of the field surface. There are three operations used in haymaking to manipulate the swath: tedding, swath inversion and raking (Rotz, 1995). Tedding is a useful method to seed up the drying rate by moving the bottom to upper surface. Tedding requires a 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 and Bare, 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 and Bare, 1963; Savoie *et al.*, 1982). And legume showed more loss than grass because of the drop of leaves (Savoie, 1987).

2.4.1 Tedding time

There are different air temperatures and sunlight intensity at different time even in the same day. And the temperature and humidity could affect the respiration and enzyme activity of plant. So it' s necessary to consider if the tedding time will affect drying rate, and how much it will be affected.

2.4.2 Tedding frequency

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 Persian clover. The content of CP decreased as tedding frequency increased. AND, NDF of tedding 3times 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 ANF and NDF, but effected CP and RFV (Park *et al.,* 2013).

2.5 Baling

Hay should be baled when moisture content below 20% (Pitt. 1991). Moisture level plays a crucial role in making hay at maximum quality. Hay baled too wet will give a suitable surroundings to fungal and aerobic bacterial for growth. Nutrition loss will be caused with the moisture wastage causing low quality hay (Michael *et al.,* 1987). It also will be at a risk for heating and spontaneous combustion (Tomes *et al.,* 1990). However, hay baled too dry will lose its dry matter and total digestible nutrients. Alfalfa hay lost 4.3% DM on average during storage when baled with 18% moisture content, and increased 0.7% for each percentage unit increase in moisture content (Buckmaster and Heinrichs, 1993). Avoiding the effect of weather, air humidity and other uncontrollable elements, it is important to speed up the baling process.

2.6 Spontaneous combustion

It is very important to control the moisture content of hay. If hay is stacked with wet grass, haystacks will produce internal heat due to bacterial fermentation. And the produced heat can be sufficient to ignite the hay causing a fire. Hay is considered fully dry when it below 20% moisture (Pitt. 1991). Heat is produced by the respiration process, which occurs until the moisture content of drying hay drops below 40%. Good hay (content around 16% moisture) heat little, but hays baled at about 25 % moisture could heat to about 45° C mainly contained with *Aspergillus glaucous*. And when initial moisture contents arrived 40 %, it became very hot (60° C ~ 65° C) and contained a large number of flora of thermophilic fungi (Gregory *et al.*, 1963). Combustion problems typically occur within five days to seven days of baling. A bale cooler than 49 ° C is in little danger. If the temperature of a bale exceeds more than 60 ° C, it can combust. Bales between 49 ° C and 60 ° C need to be removed from a barn or structure and separated to cool them off. Moisture content of baling stage and ambient temperature during preservation had a major effect on hay quality (Tomes *et al.*, 1990).

3. Materials and methods

3.1. Study site and experimental materials

These experiments were conducted in Pyeongchang Campus of Seoul National University in Korea. The experiment field located in mountain, averages about 600−700 meters above sea level. It has a humid continental climate, with four different seasons, spring is warm and humid, beside the winter is cold and long. During these experiments (5 May~9 May 2016), the average temperature is 11 ℃, average amount of precipitation is 4.8mm, average wind speed is 4.7m/s, and the average humidity is 66.1%. Other details of meteorological data during the experimental period were showed in Table 2.

Rye (*Secale cereale* L.) is a grass grown extensively as a grain, a cover crop and a forage crop= rye used in this experiment was planted on 25 September in 2015 and harvested at heading stage on 5 May in 2016 with mower conditioner.

Table 1. Agronomic characteristics of rye used in this experiment

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

Table 2. Meteorological data during the experimental period in Pyeongchang, 2016

Date	Average temperature	Highest temperature	Lowest temperature	Precipitation	Evaporation capacity	Average wind speed	Average humidity	Insolation duration
	(℃)	(℃)	(℃)	(mm)	(mm)	(m/s)	(%)	(hr)
2016.5.5	14.3	21.8	8.0	0	4.9	4.2	35.5	11.5
2016.5.6	13.8	18.0	9.9	1.1	5.0	5.7	78.6	3.4
2016.5.7	11.6	19.5	4.9	0	5.2	4.2	60.8	12.7
2016.5.8	13.1	21.0	1.7	0	5.3	2.1	55.4	10.8
2016.5.9	14.6	21.7	7.1	0	5.5	1.8	56.8	8.9
Mean	13.5	20.4	6.3	0.2	5.2	3.6	57.4	9.5

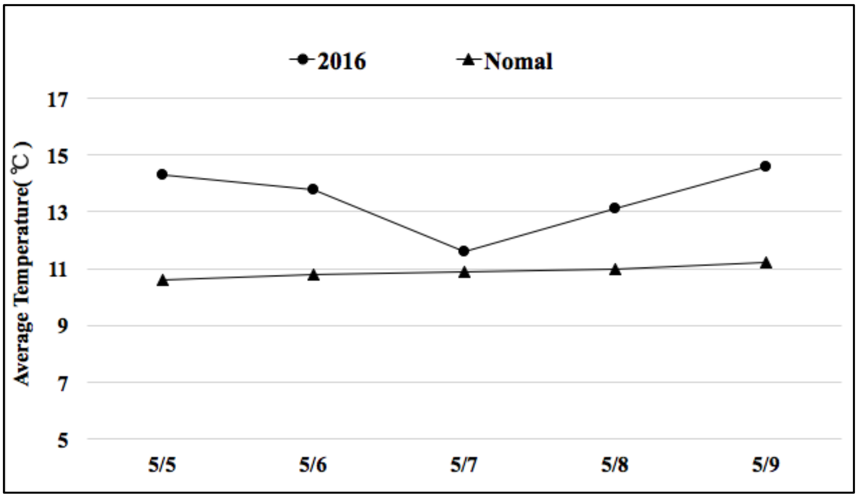

Fig. 1. Comparison of average air temperature during the experimental period and normal years

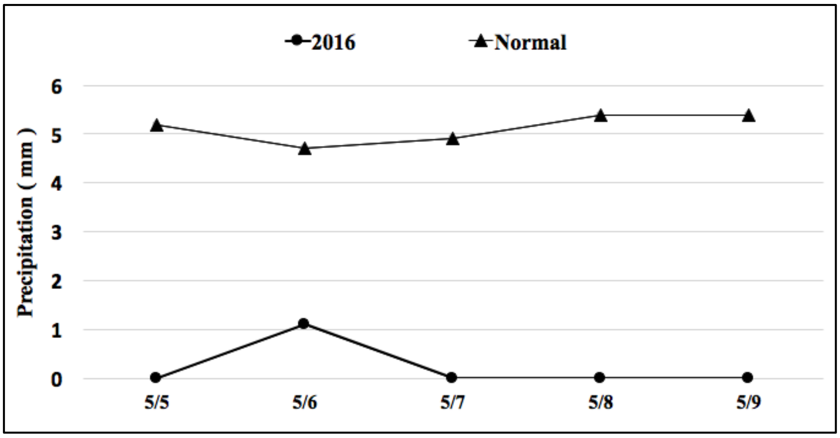

Fig. 2. Comparison of precipitation during the experimental period and normal years

3.2. Experimental design

Experiments were established in a homogeneous area within a fenced area at total of 10 m^2 (5m x 2 m) plots. Plots were separated from each other by 1m strips. Treatments were randomly assigned to the plots.

3.2.1 Trial 1– Chemical conditionings

Two different chemical conditionings, potassium carbonate (K_2CO_3) and sodium carbonate (Na_2CO_3) were used for this experiment. Twenty liters of 2% chemicals were sprayed evenly using aerosol distributor before cutting. So this experiment was divided into three treatments: potassium carbonate (K_2CO_3), sodium carbonate (Na_2CO_3), and without chemical conditioning. Hay was tedded regularly 9:00 for one time per day to make hay drying evenly , and sampled three times (9:00, 13:00 and 17:00) per day to measure moisture content (MC).

3.2.2 Trial 2– Tedding time

This experiment was divided into three different tedding time: tedding just at 09:00, 13:00 and 17:00 per day. Hay was sampled regularly three times (9:00, 13:00 and 17:00) per day to measure moisture content (MC).

3.2.3 Trial 3– Tedding frequency

Across to tedding frequency, this experiment was divided into four treatments: tedding only one time, two times, three times and without tedding. Hay was sampled regularly three times (9:00, 13:00 and 17:00) per day to measure moisture content (MC).

3.2.4 Trial 4– Cutting height

Rye was harvested into two different heights: the rest part is 8cm and 15cm to investigate the influence of cutting height on drying rate and quality on rye hay. Hay was tedded regularly 9:00 for one time per day to make hay drying evenly. And sampled three times (9:00, 13:00 and 17:00) per day to measure moisture content (MC).

3.3. Hay preservation

All treated hay samples were stored in Nylon bag tightly and preserved in a dark–dried room in ambient temperature for two months (11 May~11 July, 2016).

3.3.1 Temperature record

Temperature was recorded during the preservation progress for two months (11 May~11 July, 2016). Dial probe thermometers with 50mm size dial and 300mm size stainless were put into each Nylon bags of samples to check the variation of temperature. And the results were recorded at 13:00 per day during two months.

3.3.2 Visual score evaluation

After two months' preservation, the hay samples were evaluated in visual score (leafiness, odor, color, softness and mold) and dry matter loss. Visual score was estimated by the criterion written by Burns and Gary (1991) showed in Table 3. Dry matter loss was measured as difference of hay bale weight between baling and after preservation for two months.

Table 3. Score card for visual hay quality evaluation

Characteristic	Description	Range	Score
Stage of harvest	1. Before blossom or heading	26−30	
	2. Early blossom or early heading	21−25	
	3. Mid−to−late bloom or head	16−20	
	4. Seed stage	11−15	
Leafiness	1. Very leafy	26−30	
	2. Leafy	21−25	
	3. Slightly stemmy	16−20	
	4. Stemmy	11−15	
Color	1. Natural green color of crop	13−15	
	2. Light green	10−12	
	3. Yellow to slightly brownish	7−9	
	4. Brown or black	0−6	
Odor	1. Clean − "crop odor"	13−15	
	2. Dusty	10−12	
	3. Moldy − mousey or musty	7−9	
	4. Burnt	0−6	
Softness	1. Before blossom or heading	13−15	
	2. Early blossom or early heading	10−12	
	3. Mid−to−late bloom or head	7−9	
	4. Seed stage	0−6	

		Subtotal
Penalties	Trash, weed, dirt, mold and other material	Subtract 0−35
Scoring	>90	Excellent
	80−90	Good
	65−79	Fair
	<65	Poor

3.3.3 Viable count of fungi

Spread−plate method was used for viable counting of fungi (Michael Madigan *et al.*, 2012). The principle of viable counting is that each viable cell can grow and divide to yield one colony, so, colony numbers are the reflection of cell numbers. Total dilution was mixed by 1g of samples and 9ml 0.85% NaCl. Then samples were pipetted onto surface of PDA agar plate and spread evenly over surface of agar using one−off plastic spreader. After 3 days, check the results numbers of fungi on the surface of plate.

3.4. Chemical analysis

3.4.1 Preparation of chemical analysis

During the 4 trials, all the samples were collected about 300g and stored at dark−dried room packed into Nylon net bag, using for further chemical analysis. To get the dry matter content, collected samples were put into air−forced drying oven at 65° C for 72 hours. After the samples being completely dried, all ground through the Wiley mill with 1 mm screen prior to analysis. Then the grounded samples were put them into 3 clean plastic bottles for preservation.

3.4.2 CP analysis

Crude protein (CP) was measured by Dumas method (Jean−Baptiste Dumas, 1826). And Italy machine "Automatic Elemental Analyzer Euro Vector EA3000" utilized from 1997 was used for CP analysis.

3.4.3 Fiber analysis

Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined by the method of Goering and Van Soest (1970). Machine "ANKOM 2000 Automated Fiber Analyzer" from America was used for ADF and NDF analysis.

3.4.4 IVDMD analysis

The two−stage technique (Tilley and Terry, 1963) was used for determining *in vitro* dry matter disappearance (IVDMD) for a period of 72 hours.

3.4.5 The calculate method of RFV

Relative feed value (RFV) is very important for hay estimate, it can be calculated by known ADF and NDF (Holland *et* *al.*, 1990):

$$DDM\ \% = 88.9 - 0.779 \times ADF\ \%$$

$$DMI\ \% = \frac{120}{NDF\ \%}$$

$$RFV = \frac{DMI\ \% \times DDM\%}{1.29}$$

3.4.6 The calculate method of TDN

Total digestible nutrient (TDN) can be calculated by known ADF (Holland *et al.*, 1990):

$$TDN = 88.9 - 0.79 \times ADF\ \%$$

3.4.7 Calculating MC (moisture content)

Forage moisture content is calculated by the following formula:

Forage moisture content % =

$$\frac{(\text{Wet forage weight} - \text{dry forage weight})}{\text{Forage weight}} \times 100$$

3.5. Statistical analyses

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.

4. Results and Discussions

4.1. Trial 1 – Effect of chemical conditionings on rye hay

4.1.1 Drying rate

The treatment of K_2CO_3 speed up drying rate of rye hay and was the first plot to arrive at the level that MC below 20%, while Na_2CO_3 was almost ineffective on drying rate of rye hay. All of the three treatments achieved a moisture concentration below 20% in four days as 16.4%, 17.6%, and 18.2% respectively (Fig.3). As same result as Jaster and Moore (1992); Hong *et al.* (1987); Rotz *et al.* (1984) that addition of K_2CO_3 did decrease drying time of alfalfa. And it also was proved by Park (2013) that drying date of Italian ryegrass was shortened around 1–1.5 days by spraying with chemical conditioning. However, it was observed that chemical conditioning showed no effects on speeding up drying rate on grass plant. (Shan *et al.*, 2006). The similar result with Rotz and Davis (1986) that drying performance was better in K_2CO_3 alone than K_2CO_3 and Na_2CO_3 mixture. In another experiment, Rotz *et al.* (1987) proved that the influence of chemical conditioning depends on cutting frequency. Chemical conditioning is the most effective on second and third cuttings, less effective during first cutting because greater crop yields created thicker swaths. Even, some papers showed that chemical conditioning is effective on legume species and grass−legume mixes, but has no effect on grass species alone (Seo *et al.*, 2000). According to the legume−grass mixed hay trial by Beauregard *et al.,* (1990), chemical conditioning with alkaline carbonate (K_2CO_3) solution increased the first−day drying rate in the first cutting hay under favorable weather condition. But chemical conditioning did not improve the drying rate in second cutting hay under more humid weather condition. As a result, influence of chemical conditioning on drying rate of hay depends on the species of crops and cutting frequency and weather condition. Because the principle of chemical conditioning is speeding up moisture loss though opening the stoma of forage, and different conditionings will develop different physiological features of stoma.

4.1.2 Quality

The treatment of K_2CO_3 increased the quality of rye hay slightly (Table 4). It showed higher IVDMD and RFV ($p<0.05$). However, K_2CO_3 did not show significant different in content of CP, ADF and NDF ($p>0.05$). The treatment of K_2CO_3 contained less moisture before being baled, the living environment is less ideal for microbes, resulting it contained less fungi during preservation compared with others ($p<0.05$) (Table 6). In agreement with the result described by Shan (2006) that chemical conditioning improved in vitro digestibility of alfalfa. CP, ADF, NDF, and digestibility of DM was improved in cows by K_2CO_3 (Hong *et al.*, 1987). In another experiment also showed that chemically conditioned hay had a higher CP content than untreated hay when both were dried under relatively good drying conditions (Ehle *et al.,* 1985). On the other hand, treatment Na_2CO_3 of this experiment didn' t show a big difference with putting no chemical conditioning ($p>0.05$).

In this experiment, the treatment of K_2CO_3 lost less dry matters compared with other treatments ($p<0.05$) (Fig.4). The same result in another experiment on alfalfa made by Johnson et al. (1983) also showed the measurements of visual and quality, bale temperature and DM loss of spraying with K_2CO_3 were greater than controls. It also was proved by Rotz *et al.* (1983) that loss of DM was higher in control than chemical conditioning treatment during preservation process. Chemical conditioning could increase harvest yield of over 10% in alfalfa hay production (Rotz *et al.,* 1989). But the process with chemical conditioning appeared to have little influence on plant respiration and the relevant losses (Rotz *et al.,* 1984).

4.1.3 Visual estimation

Visual scores of both treatment K_2CO_3 and without chemical conditioning are good (82 and 84). But treatment $NaCO_3$ was fair (77). Because it had less leaf proportion, more dust compared with others (Table 5). In another experiment of grass hay, it showed the visual scores of treatments combined K_2CO_3 with mower-conditioning were all good, but those K_2CO_3 alone and control experiments were fair (Seo *et al.*, 2000). And it also was proved that the amount of mold and yeast increased with increasing of temperature and preservation time (Wang *et al.*, 2014).

4.1.4 Temperature change

All the temperature of treatments dropped down at the first week of storage. Then continually increased along with slight fluctuation until the temperature maintained in a stable temperature around 25 ° C after one-month preservation. It also was discovered that all the temperature of treatments was affected by ambient temperature. Besides, the treatment of $NaCO_3$ showed more obvious fluctuation than others during the first month (Fig.5). All the temperature of rye hay bales maintained under ambient temperature during first 16 days (11 May~27 May), however, from 27 May the temperature of treatments became higher than ambient temperature. The similar result with Han (1995) that in the first 6 days, different species of bales could keep temperature under air temperature, but from 7th day the temperature suddenly increased a lot and higher than air temperature.

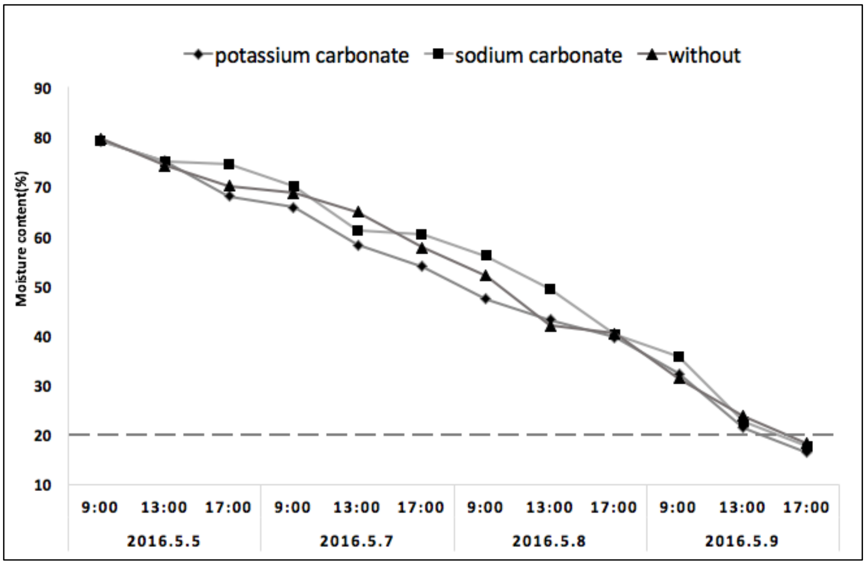

Fig.3. Effect of chemical conditioning on the drying rate of rye hay

Table 4. Effect of chemical conditioning on the forage quality of rye hay

Chemical conditioning	CP	ADF	NDF	IVDMD	TDN	RFV
		-----------%	-----------			
Herbage	7.9	34.9	57.9	74.5	61.4	99
K_2CO_3	7.3	35.2	59.0	74.9	60.1	97
Na_2CO_3	6.9	36.0	60.1	70.5	60.5	94
Without	7.6	35.8	59.3	70.0	60.7	96
Mean	7.3	35.6	59.5	71.8	60.8	96
LSD(0.05)	NS	NS	NS	3.33	NS	1.44

Table 5. Effect of chemical conditioning on the visual score of rye hay after preservation

Chemical conditioning	Visual score *						
	Stage of harvest	Leafiness	Color	Odor	Softness	Mold/ Dust	Total
K_2CO_3	30	22	11	14	8	−3	82
Na_2CO_3	30	21	10	13	8	−5	77
Without	30	23	12	14	8	−3	84
Mean	30	22	11	14	8	−4	81

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

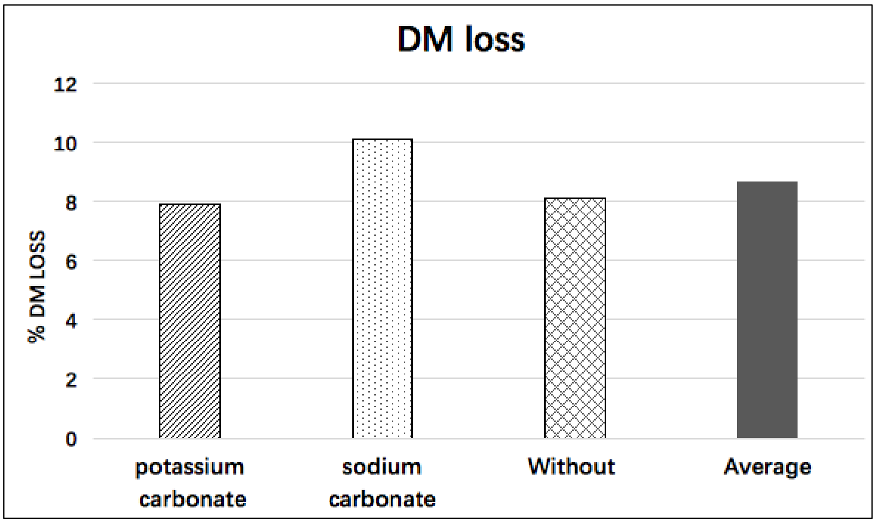

Fig.4. Effect of chemical conditioning on the DM loss of rye hay

Table 6. Effect of chemical conditioning on the viable count of fungi in rye hay after preservation

Chemical conditioning	Viable count of fungi
	CFU/g
K_2CO_3	2.4×10^6
Na_2CO_3	2.2×10^7
Without	1.6×10^7
Mean	1.3×10^7
LSD(0.05)	6.36×10^6

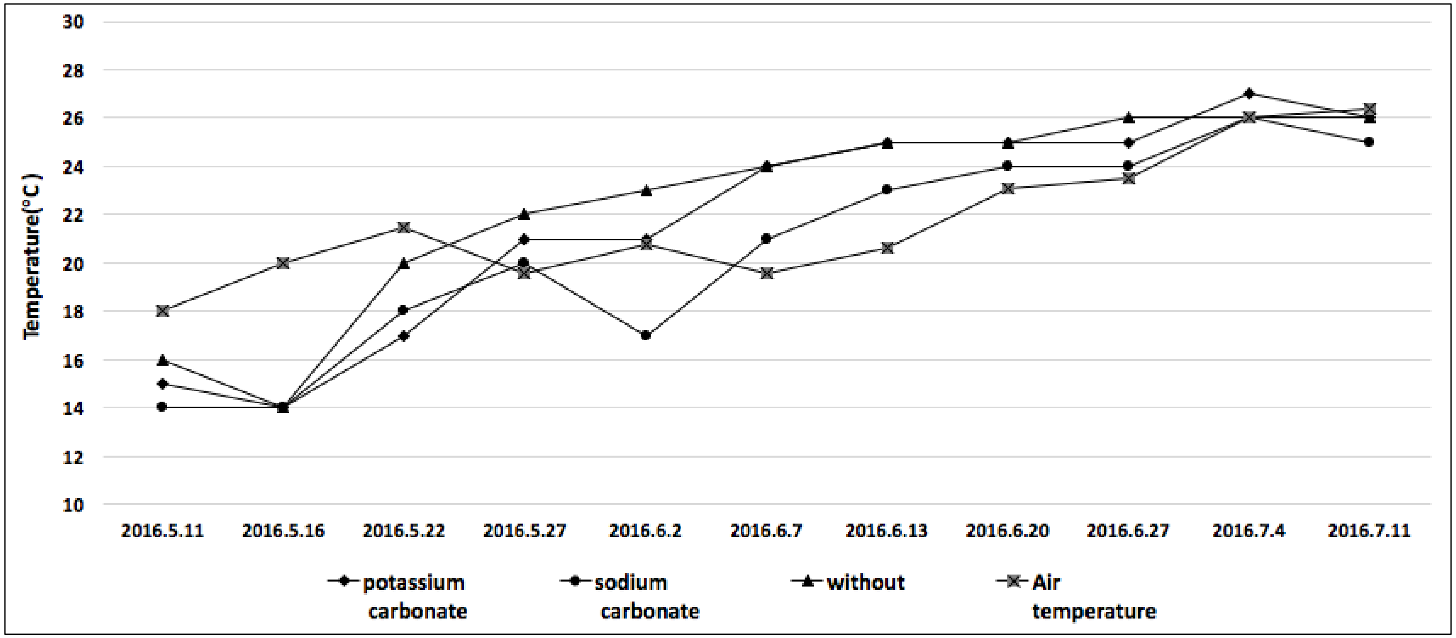

Fig. 5. Temperature record of experiment 1 (chemical conditioning)

4.2. Trial 2– Effect of Tedding time on rye hay

4.2.1 Drying rate

The result showed that the field drying rate of rye hay was the highest in tedding at 9:00 (Fig.6). Tedding at 9:00 and 13:00 were more effective on speeding up the drying rate compared with tedding at 17:00. Because the two treatments had more time to lose their moisture of bottom after tedding. Besides, the sun light intensity and air temperature are higher during noon. But the difference was not too obvious. In addition, it was proved that both temperature and humidity could affect respiration of grass samples (Parices and Greig, 1974). And respiration would transfer DM to heat, caused more losses as well (Rotz and Muck, 1988). Result from Savoie (1988) showed that when moisture content decreased from 800 to 300g/kg, the material loss would increase from 60% to 80%. Tedding at 9:00, 13:00 and 17:00 all achieved a moisture content less than 20% in four days 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 (2013) that tedding was ineffective after 3 days. Tedding could reduce the risk of nutrition losses due to unideal weather, but might increase mechanical losses (Murdoch *et al.*, 1963). Impeller and roller samples of tall fescue arrived moisture content under 20% in 2-3 days at 13:00 (Kim *et al.*, 2016).

2.2 Quality

Tedding at 17:00 showed lower in NDF content ($p<0.05$), and had higher level of RFV compared with tedding at 9:00 and 13:00 ($p<0.05$) (Table 7). But these three treatments didn't be discovered obvious difference on content of CP, ADF, IVDMD, TDN ($p>0.05$) (Table 8). 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.7). It has been proved that the loss form tedding was 1-3% of the whole crop yield, but the loss could be more during real process (Ciotti and Cavallero, 1979). Tedding losses of field were 1-4% for alfalfa, while just around 0.5% for timothy (Savie 1987). And laboratory estimation indicated that the yield losses of very dry legumes could exceed 20% due to tedding (MacAulay and Bilanski, 1968; Savoie, 1988).

Lima (2015) state that hay baled over 20% moisture has a high probability of developing mold, which will decrease the quality of hay by decreasing protein and total nonstructural carbohydrates and the mold will make the hay less palatable to animal and could be toxic, especially horse. In this experiment tedding, at 9:00, 13:00 and 17:00 did showed marked difference on viable count of total fungi after preservation ($p>0.05$) (Table 9). There are not many other papers related to tedding time, but higher temperature and humidity of air affect plant respiration and enzymatic activity. So, cutting in the afternoon showed higher concentrates of plant sugars compared with harvesting in humidity morning and hot noon (Dirk and John, 2015). It is reasonable to speculate that tedding time effected quality of hay because of the temperature and humidity of air.

4.2.3 Visual estimation

Visual scores of all treatments were good (80, 82, 85). Although they were all good, tedding at 17:00 got higher score than others. Because it had more leaf proportion, and delighter odor (Table 8). Han (1995) proved that the species with high moisture content got lower visual scores, easily showed dark color and contained more fungi and mold during preservation.

4.2.4 Temperature change

All the temperature of treatments dropped down slightly at the first week of storage. Then continually increased until maintained in a stable temperature around 25 °C after one-month preservation. In this process temperature of bales showed evident influence of air temperature, when ambient temperature dropped on 3 June, All the temperature of treatments dropped down as well. Besides, tedding at 13:00 showed the highest temperature, while tedding at 17:00 was the lowest temperature among the experiment during storage. The temperature of tedding at 17:00 was under ambient temperature during the whole storage, while tedding at 9:00 maintained the temperature below ambient for around one and half months (11 May~20 June). But tedding at 13:00 showed higher temperature than air just from around 3nd week (23 May) (Fig.8). Han (1995) proved that the species maturated quicker with less moisture content showed lower temperature during preservation. Rotz and Muck (1999) also stated that heating during the first month of storage helps dry the hay. After the first month, hay would be relatively stable during the remaining storage period.

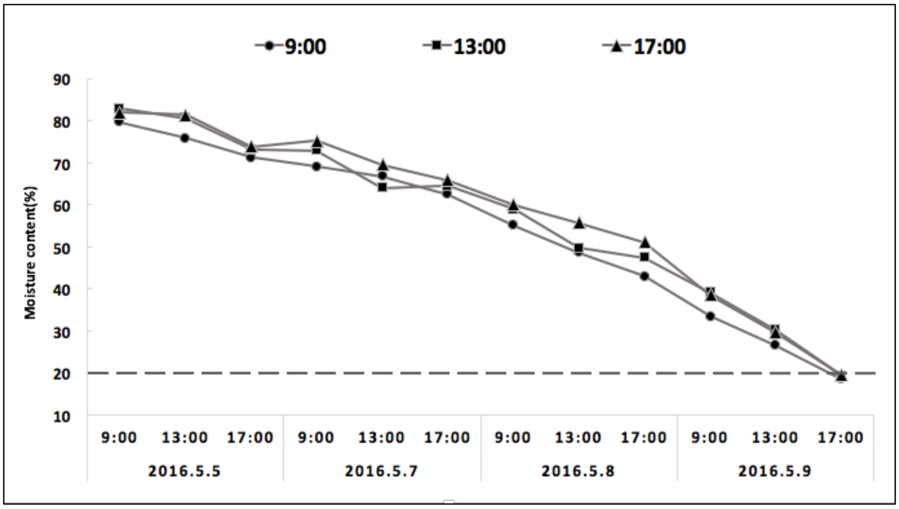

Fig. 6. Effect of tedding time on the drying rate of rye hay

Table 7. Effect of tedding time on the forage quality of rye hay

Tedding time	CP	ADF	NDF	IVDMD	TDN	RFV
	-----------%	-----------				
Herbage	8.2	36.1	58.8	73.6	60.4	96
9:00	9.0	36.0	59.6	71.4	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

Table 8: Effect of tedding time on the visual score of rye hay after preservation

Tedding time	Visual score *						
	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

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

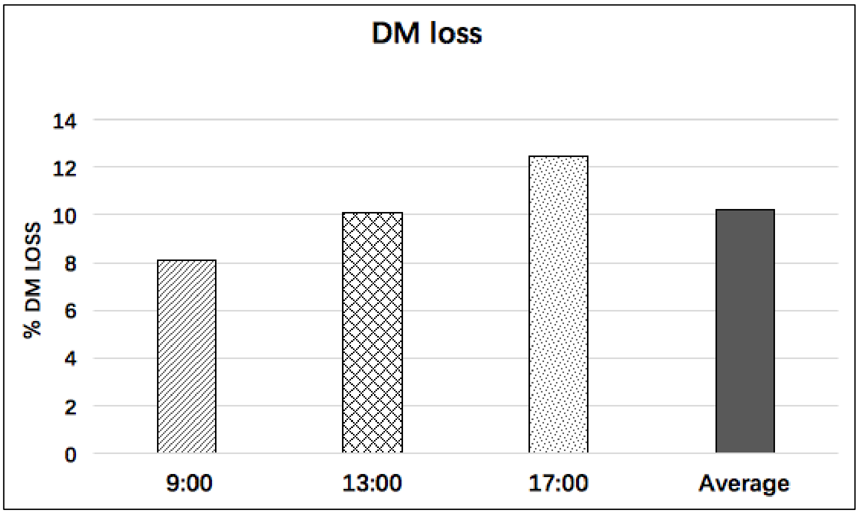

Fig. 7. Effect of tedding time on the DM loss of rye hay

Table 9. Effect of tedding time on the viable count of fungi in rye hay after preservation

Tedding time	Viable count of fungi
	CFU/g
9:00	6.7 x 10^7
13:00	4.8 x 10^7
17:00	4.3 x 10^7
Mean	5.1 x 10^7
LSD(0.05)	NS

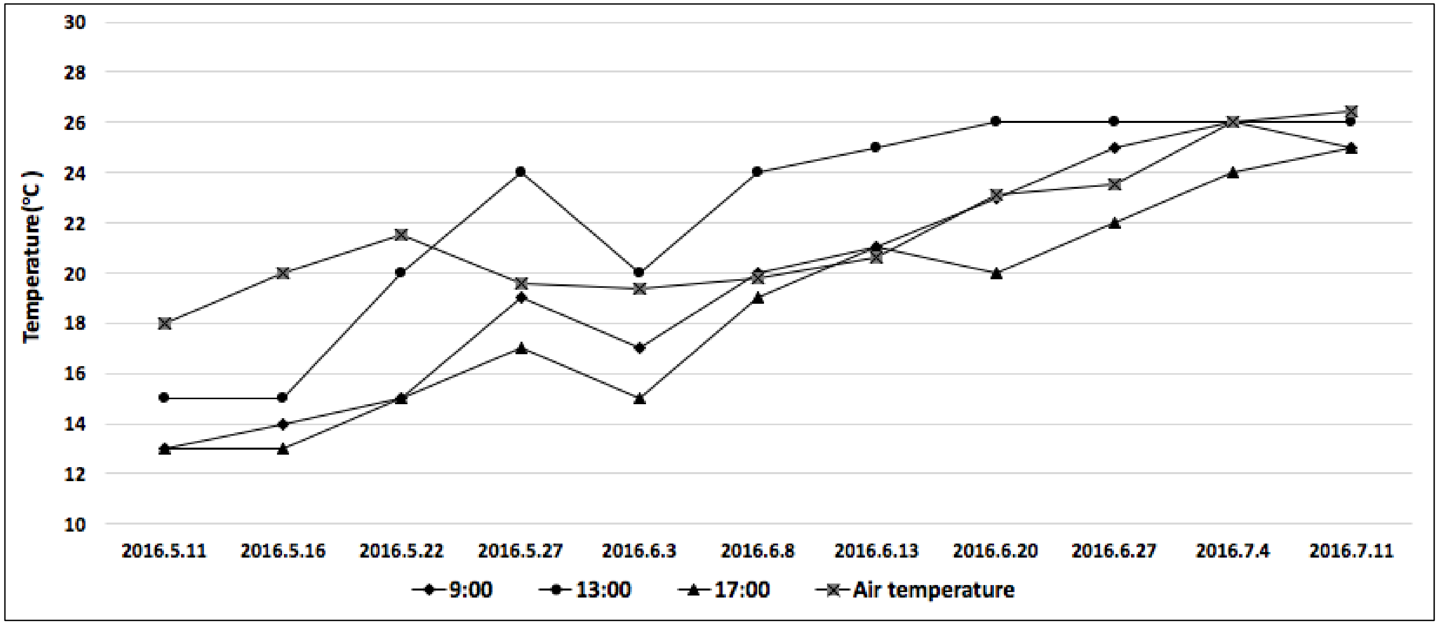

Fig. 8. Temperature record of experiment 2 (tedding time)

4.3. Trial 3 – Effect of Tedding frequency on rye hay

4.3.1 Drying rate

The result showed that the field drying rate of rye hay was the highest when tedding in 3 times per day. Tedding in 1, 2 and 3 times per day all achieved a moisture content below 20% in four days as 18.2%, 17.8%, and 17.3% respectively (Fig.9). But no tedding plot could not reach the MC below 20% on the fourth day. Except for without tedding treatment, all treatments showed positive influence on the drying rate of rye hay. So tedding frequency is very important to speed up the drying rate of rye hay. 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 by Park (2013) that drying rate of Italian ryegrass also had been affected by tedding frequency within 3 days after it was cut. Han (1995) also showed the similar result that tedding 3 times per day speed up the dry rate of oat hay compared with tedding 1time per day. 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 more yield loss. And it also was discovered that legume got more influence in yield decrease by tedding, because of higher leaf proportion than grass (Mac and Bilanski,1968; Savoie, 1988; Rotz and Muck, 1988; Taylor *et al.*, 1979). Tedding was more efficient in wet condition, such as after moving or rain (Pattey *et al.*, 1986).

4.3.2 Quality

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 ($p<0.05$), higher in TDN and RFV ($p<0.05$) (Table 10), showing an obvious improvement on decreasing DM loss ($p<0.05$) (Fig.10), and contained less fungi during conservation compared with the without tedding treatment ($p<0.05$) (Table 12). Because the plot 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 has been discovered within these four treatments ($p>0.05$). On the other hand, there is no significant difference when tedding within three times.

As a result, tedding is necessary to increase the quality of rye hay, but frequent tedding will cause more DM loss. The similar result as Rethman and Beukes (1977), that tedding frequency made a negative effect on DM production and CP content especially in leafy stage. DM losses of swichgrass during first 6 months were 13% compared with original bale dry weight (Sanderson *et al.*, 1997). Results in other papers showed that tedding frequency was not effect on ADF and NDF, but effect CP and RFV of alfalfa hay (Park *et al.*, 2013). Experiment on clovers 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. But there was another experiment on tall fescue showed different result that tedding frequency did not affect significantly the content of ADF, NDF, RFV, CP (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).

4.3.3 Visual estimation

Visual scores of tedding just 1 time and 2 times per day were good (84 and 85), but tedding 3 times per day was fair and without tedding showed in poor (64) (Table 11). The reason that tedding 3 times got fewer score than 1 and 2 times is it had less leaf proportion and yellow color. Too frequent tedding lost more leaves, causing more DM loss. But as for color, yellow and brown hay also could be high quality hay. It depends on witch reason causing color fading. Because both sunshine and rain can bleach hay and lose its green color (Rocateli and Zhang. 1990). Therefore, the brownish color might indicate low nutrient content because of rain leaching or high quality related to sun bleaching. The treatment without tedding showed dark color, mildew and rotten odor, harsh texture and contained more mold due to high moisture content before baling. It also was proved by Rocateli and Zhang (1990) that high moisture content usually drives dark green, brown or black or may not be good quality hay.

4.3.4 Temperature change

All the temperature of treatments dropped down at the first week of storage. According to these records, although the temperature fluctuation of samples was obvious in the first month, with the time went on, almost all the other samples trended to maintain in a stable temperature around 25° C, except for the without tedding treatment. Besides, the experiment−without tedding got more evident fluctuation than others, and it arrived the temperature around 30° C after two months' preservation (Fig.11). The reason of this phenomenon is that the treatment-without tedding didn' t arrive the target moisture content of 20% before preservation. And the moisture would increase the heat of hay bales (Gregory *et al.*, 1963). Another experiment showed that tedding 3 times per day was higher in temperature than tedding only 1 time per day during preservation (Han. 1995). Rotz and Muck (1999) also demonstrated that in hay containing high moisture, microbial respiration causes the hay to heat during the first 3 to 5 weeks of storage.

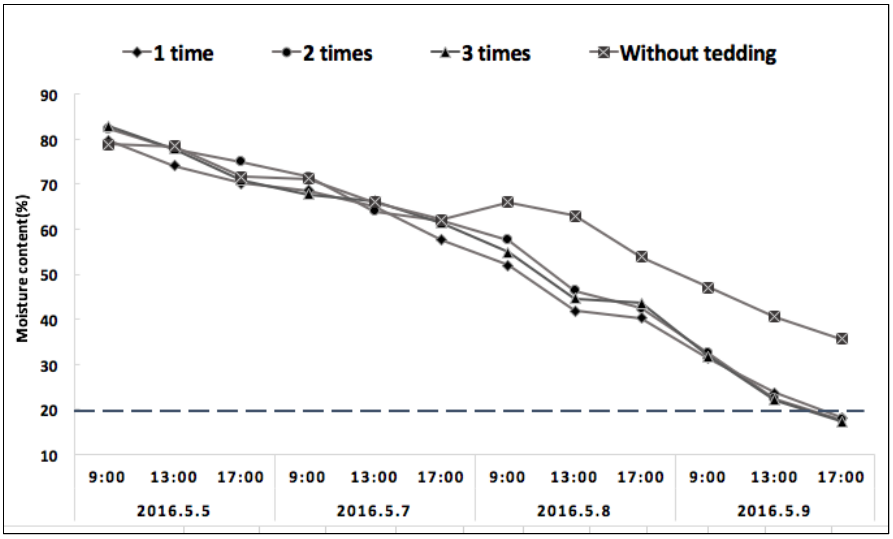

Fig.9. Effect of tedding frequency on the drying rate of rye hay

Table 10. Effect of tedding frequency on the forage quality of rye hay

Tedding frequency	CP	ADF	NDF	IVDMD	TDN	RFV
	-----------	-----------	%	-----------	-----------	
Herbage	7.4	36.3	59.9	72.8	60.2	94
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

Table 11. Effect of tedding frequency on the visual score of rye hay after preservation

Tedding frequency	Visual score *						
	Stage of harvest	Leafiness	Color	Odor	Softness	Mold/ Dust	Total
1time	30	26	11	13	8	−4	84
2times	30	25	10	14	8	−3	85
3times	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 Poo

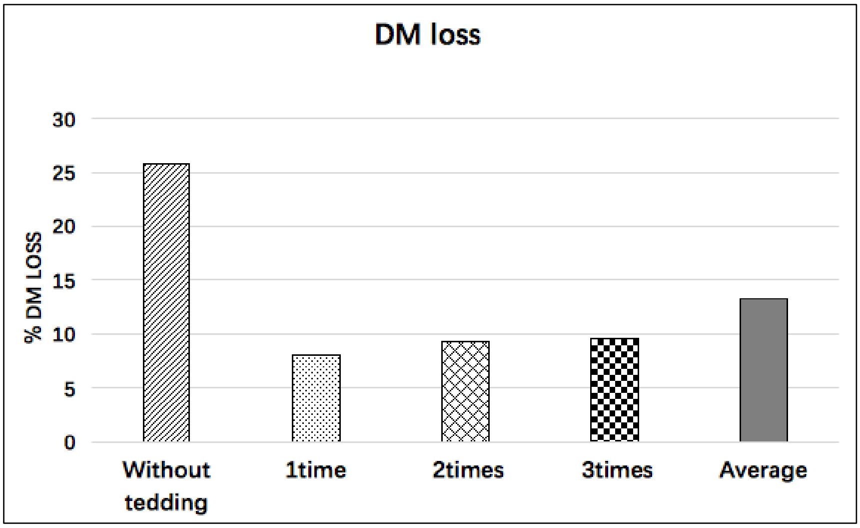

Fig. 10. Effect of tedding frequency on the DM loss of rye hay

Table 12. Effect of tedding frequency on the viable count of fungi in rye hay after preservation

Tedding frequency	Viable count of fungi
	CFU/g
1 time	2.4×10^6
2 times	6.1×10^6
3 times	5.6×10^6
Without	4.2×10^7
Mean	1.4×10^7
LSD(0.05)	1.96×10^6

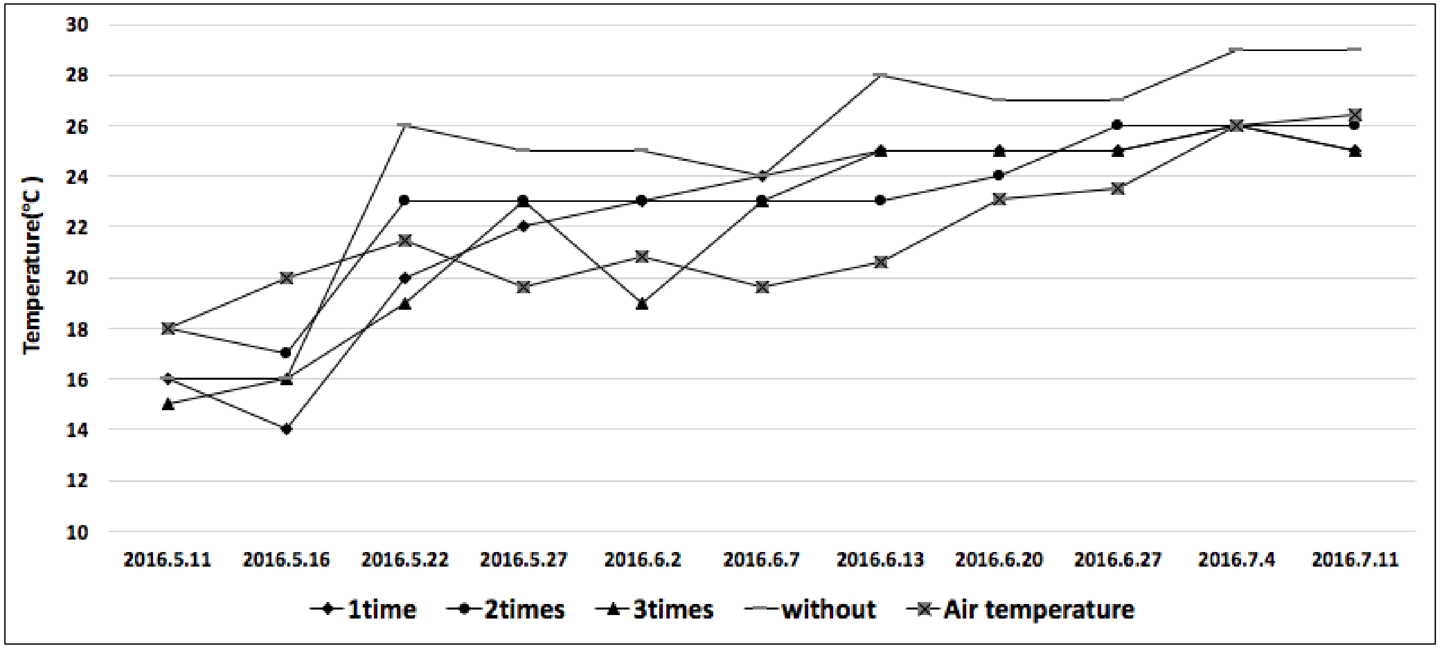

Fig. 11. Temperature record of experiment 3 (tedding frequency)

4.4. Trial 4 – Effect of Cutting height on rye hay

4.4.1 Drying rate

Cutting in the height 15cm away from ground lost moisture faster than cutting in 8cm. Because cutting height being 15cm had less biomass and got better ventilation than 8cm. However, the difference was not obvious. It might because both the two treatments were harvested by mover with mechanical conditioner. Mechanical conditioner made the difference of treatment becoming smaller. And on the fourth day of experiment period, both treatments achieved a moisture concentration below 20%. Cutting height was related in the yield of forages. Curran and Posch (2000) reported about 12% decline in DM yield between cut heights that left 10.2 vs. 50 cm. Increasing the cutting height of corn at harvest also improved its nutritive value by reducing the concentration of NDF, ADF and ADL (Neylon and Kung, 2003). Cutting height had a substantial effect on *Medicago scutellata* production, it was sharply reduced by 3cm cutting (Taylor *et al.,* 1979). 4 inches cutting height resulted in lower yield than 2 inch cutting height or all harvests except for December. And stem density was a little higher for cutting in 4 inches, but the increase in stem density did not transfer into yield (Ottman and Rogers. 2000). The hay tedder generally improves the drying conditions by spreading the hay swath over large area. In this study, there was no significant difference in achieving a moisture content below 20%, because the field was ted generally once per day.

4.4.2 Quality

Cutting in 15cm showed higher in CP content ($p<0.05$) (Table 13) compared with cutting in 8cm. Reported changes in CP concentration during hay storage range from a moderate loss (Davies and Warboy, 1798) to no change (Nelson, 1972). Rotz and Abrams (1988) reported that the change in CP concentration is often insignificant and a small increase can occur with high carbohydrate loss in high-moisture hay.

The top half of the grass forage has a higher percentage of digestible nutrients and less fiber than the bottom half of the plant. This occurs because the lower-stem sections are more mature and tend to be woodier compared to the less mature top portion (Bolormaa. 2008), but it also depends on the species. In general, we always think that cutting in 8cm have more fiber and harder to digest since it has more biomass. But the two treatments didn’t show significate difference in content of ADF, NDF, IVDMD, TDN and RFV ($p>0.05$) (Table 13), even showed ineffective in the amount of total fungi during preservation. ($p>0.05$) (Table 15). Daniel *et al.* (2007) stated that one of reasons for leaving taller stubble is to improve the quality of the forage harvested. The lowest sections of alfalfa plant are typically higher in fiber and have fewer high quality leaves present. A Nebraska study (Ogden and Kehr, 1968) where the top half of a full bloom alfalfa canopy was separated from the bottom half indicated that a larger percentage of the digestible nutrients and less fiber was found in the top half versus the bottom half of the plant.

The digestibility of DM and many nutrient constituents decreases during storage (Davies and Warboy, 1978), but digestibility of fiber changes less than that of many other plant components (Nelson, 1968). We also found that cutting 8 cm hay decreased IVDMD and increased fiber components (ADF and NDF) compared to fresh matter. Cutting in 15cm lost more dry matters than cutting in 8cm (Fig.4). Another experiment proved that the nutritive value, IVDMD and CP declined with the reduction in leaf stem ratio (Santis *et al.,* 2004). The residue of plant affected productivity and persistence of alfalfa. Remaining about 10 cm residue would be the optimum height for loss and yield reduction (David and James. 1997). The same result as Ottman and Rogers (2000) that the most accurate cutting height of alfalfa is around 2 to 4 inches.

4.4.3 Visual estimation

Both visual scores of treatment, cutting in 8cm and 15cm, were good (83 and 85) (Table 14). But cutting in 15cm got a little higher score, because it owned more leaf proportion and contained less fungi after preservation than cutting in 8cm. It was proved that visual score also depends on harvest time. Visual score of the grass harvested at late boot was good (86), while at heading was good (80), and it was poor (63) when harvested at bloom stage (Seo *et al.*, 2000).

4.4.4 Temperature change

All the temperature of treatments dropped down slightly at the first week of storage. Then continually increased until maintained in a stable temperature around 24 °C after one-month preservation. Across the result, temperature of bales was affected by air temperature, when ambient temperature dropped on 3 June, all the temperature of treatments dropped down as well. And cutting in 8cm showed higher temperature than tedding in 15cm during preservation. The temperature of cutting in 15cm was under ambient temperature during the whole storage, while the temperature of cutting in 8cm was higher than ambient temperature from around 3nd week (23 May) (Fig.14). The reason is same as the result from Han (1995) that amount of microorganism increased with the increase of moisture content, causing more heat in hay bales during storage process. Moisture and temperature are major factors affecting populations of microbes in stored forage. Significant fungal growth in moist hay requires relative humidity to be at least 70% and temperature to be at or above 20℃ (Rees, 1982). The reason why the fungus was not high in this experiment presumably because the temperature was above 20℃ but the water content was low.

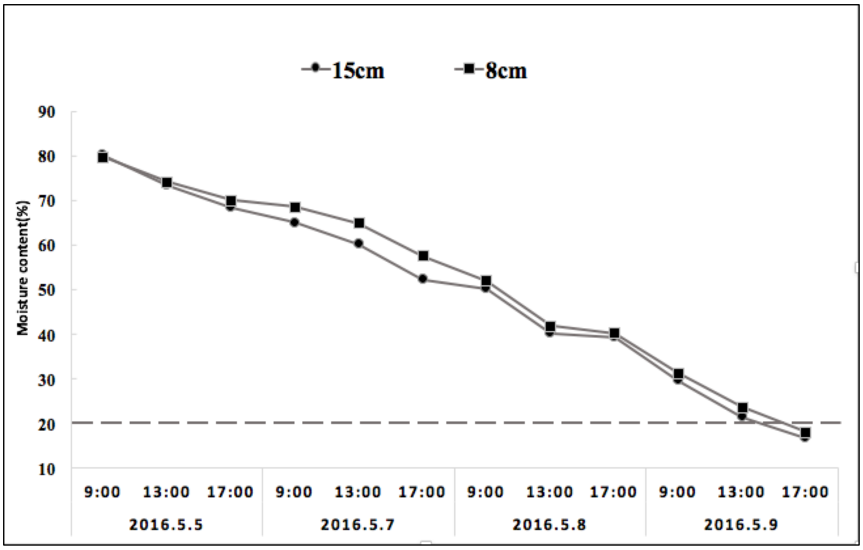

Fig. 12. Effect of cutting height on the drying rate of rye hay

Table 13. Effect of cutting height on the forage quality of rye hay

Cutting height	CP	ADF	NDF	IVDMD	TDN	RFV
cm	-------------%---------------					
Herbage	7.9	34.9	57.9	74.5	61.4	99
8	7.6	35.8	59.7	70.0	60.7	96
15	10.7	35.7	59.3	74.1	60.4	95
Mean	9.2	35.8	59.3	72.1	60.6	96
LSD(0.05)	2.46	NS	NS	NS	NS	NS

Table 14. Effect of cutting height on the visual score of rye hay after preservation

Cutting height	Visual score *						
	Stage of harvest	Leafiness	Color	Odor	Softness	Mold/ Dust	Total
8cm	30	23	12	13	8	−3	83
15cm	30	26	11	13	7	−2	85
Mean	30	25	10	12	8	−5	79

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

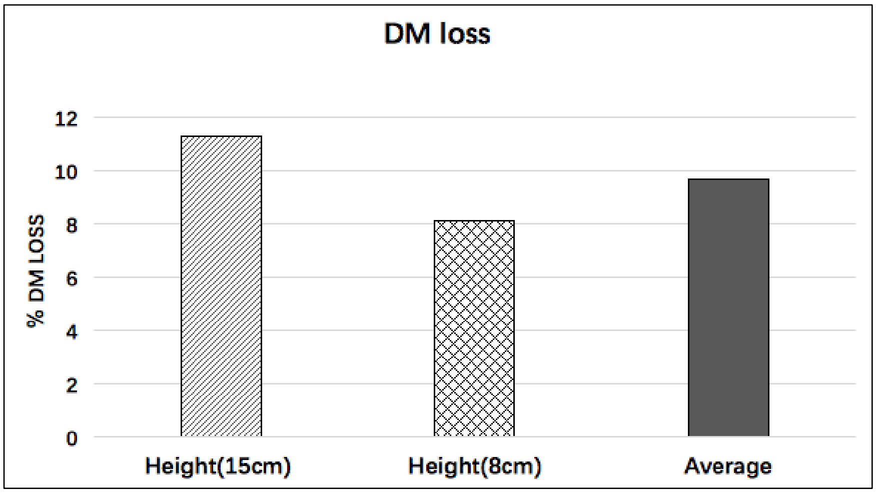

Fig 13: Effect of cutting height on the DM loss of rye hay

Table 15. Effect of cutting height on the viable count of fungi in rye hay after preservation

Cutting height	Viable count of fungi
	CFU/g
15cm	2.4 x 10^7
8cm	6.3 x 10^7
Mean	4.4 x 10^7
LSD(0.05)	NS

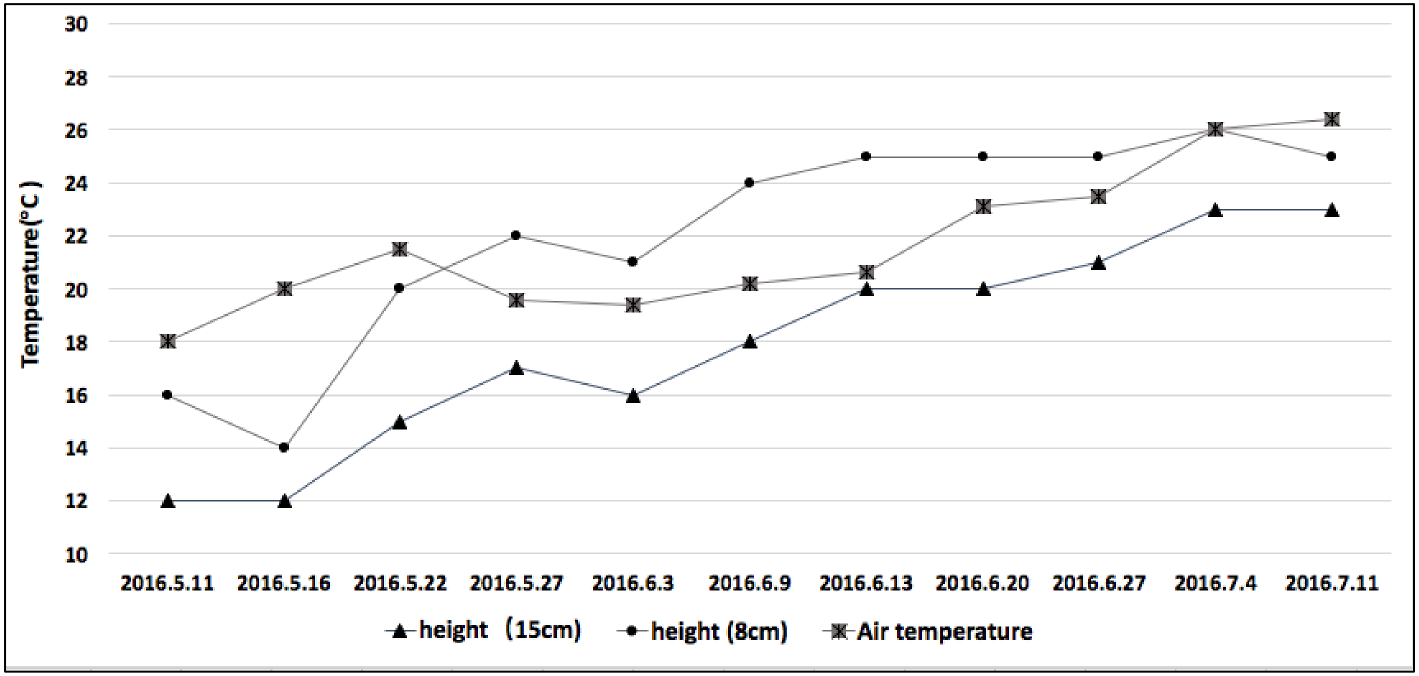

Fig. 14. Temperature record of experiment 4 (cutting height)

5. Conclusion

1). Using chemical conditioning K_2CO_3 can speed up the drying rate and improve quality slightly of rye hay. It showed higher IVDMD and RFV ($p<0.05$), got less DM loss ($p<0.05$), and contained less microorganisms during preservation compared with others ($p<0.05$). On the other hand, Na_2CO_3 showed ineffective on neither drying rate nor quality compared with the treatment sprayed no chemical conditioning ($p>0.05$). Considering the cost of chemical conditioning is not high, this research recommends using K_2CO_3 for chemical conditioning to speed up drying rate of rye hay.

2). 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.

3). 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.

4). As for cutting height, cutting in longer height (15cm) was faster on drying process due to better ventilation. Cutting in 15cm showed higher in CP content ($p<0.05$), but got more dry matter loss compared with cutting in 8cm ($p<0.05$). On another hand, cutting in 15cm and 8cm didn't show significant difference in ADF, NDF, IVDMD, TDN and RFV, even showed ineffective in the amount of total fungi during preservation ($p>0.05$). Comprehensively considering yield, quality and drying rate, this research recommends cutting rye in a shorter height around 8cm.

5). All the temperature of treatments dropped down slightly at the first week of storage. Although the temperature fluctuation of samples was obvious in the first month, almost all the samples trended to maintain in a stable temperature around 25°C, except for the without-tedding treatment. The without-tedding treatment got more evident fluctuation than others, and it arrived the temperature around 30° C after two months' preservation. So it can be proved that temperature will rise with the increase of moisture content of rye hay bales.

6). 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.

7). Above all, it is recommended spraying K_2CO_3 before harvesting, then harvesting in 8cm at heading stage to get relative higher yield and quality fresh rye. Tedding at 13:00 ~ 17:00 for 1 ~ 2 times per day is the most optimum method to speed up drying process and get higher quality hay. Checking the temperature during preservation is necessary to avoid spontaneous combustion.

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요약

계절적인 작물의 생장 편차 및 불안정한 날씨 때문에 조사료의 지속적인 공급을 위해서는 저장을 하는 것이 필수적이다. 그 중 건초는 가축 급여에 있어 널리 알려진 방법 중 하나이다. 건초 생산자는 건초의 품질 향상을 위해 최선의 방법을 선택하는 것이 중요하다. 본 시험은 서울대학교 평창캠퍼스 실험 포장에서 채취한 호밀 시료를 바탕으로 건조제 처리, 반전 시기, 반전 횟수 및 예취 높이가 호밀 건초의 건조율과 품질에 미치는 영향을 조사하기 위하여 수행되었다. 건조제는 K_2CO_3를 시용했을 때 무처리 건초에 비해 건조 속도가 빨랐으며, IVDMD는 증가하였고($p<0.05$), DM 손실은 줄어들었다($p<0.05$). 또한, 보관 중 곰팡이의 발생이 줄어들었다($p<0.05$). 반면, Na_2CO_3는 건조제를 처리하지 않은 건초와 비교하여 건조율이나 건초의 품질에 큰 차이를 보이지 않았다($p>0.05$). 오후 17:00에 반전한 건초의 NDF 함량은 낮았으며($p<0.05$), 09:00, 13:00 반전 건초에 비해 높은 RFV 수치를 보였다($p<0.05$). 반면, 후반에 반전시킨 건초에서는 DM 손실이 더 많아짐을 알 수 있었다($p<0.05$). 하루에 1~3회 반전시킨 건초의 경우 ADF와 NDF 함량은 낮았으며($p<0.05$), CP, TDN, RFV 수치는 증가하였고($p<0.05$), DM 손실률은 줄어들었다($p<0.05$). 또한, 반전하지 않은 건초에 비해 곰팡이 발생도 줄어든 것을 볼 수 있다($p<0.05$). 이에 비해 반전을 자주 시킨 건초의 경우 DM 손실률을 높이는 결과를 볼 수

있었다($p<0.05$). 15cm이상 높게 자른 호밀의 경우 건조의 진행속도가 빨랐으며, CP 함량이 높게 나타났다($p<0.05$). 그러나 15cm와 8cm 높이로 수확된 호밀은 ADF, NDF, IVDMD, TDN 및 RFV 함량에서 유의적인 차이를 보이지 않았다($p>0.05$). 이상의 결과를 종합하여 볼 때 호밀 수확 전 건조제 K_2CO_3 처리를 한 후, 지면으로부터 8cm 높이로 자르는 것을 추천한다. 또한, 13:00~17:00사이에 하루 1~2회 반전을 하는 것이 빠른 건조와 좋은 품질의 호밀 건초를 생산할 수 있는 방법임을 알 수 있다.

주요어 : 건조율, 건조제 처리, 반전 시간, 반전 횟수, 예취 높이
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