



Research Paper

A study on effective measurement methods and usage systems of moisture contents on forage

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ABSTRACT

The methods mainly used in forage in Korea were investigated. Most commonly used forages are rice straw, maize, whole wheat, and Italian ryegrass. Among those forages, dried rice-straw is used in a plastic film wrapped round bales. The other forages are used while keeping the plastic stretch film covered after preparing a round bale in a state containing a large amount of moisture content immediately after harvesting. In the case of moist forage, about 60% is suitable for promoting proper fermentation, while in round bale forage, it is important to accurately measure the moisture content so as to determine DM content in bales. However, in the case of a round bale wrapped with a plastic stretch film, which is difficult in measuring moisture content, moisture content measurement and marking cannot be performed due to film damage and quality degradation. The moisture content of the round bale was measured and analyzed by various methods such as electrical conductivity, microwave and electrical resistance. Even within the same round bale, the difference in moisture content was found to be large depending on where the sample was taken. Also, it was reported that it is difficult to measure moisture content without damaging the film in the case of a round bale wrapped with a plastic stretch film. Therefore, in order to accurately measure the moisture content of the plastic stretch film, it is required that the moisture content in a measurable manner is measured immediately after the preparation of the round bale and then wrapped with the plastic stretch film.

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INTRODUCTION

Forage cattle raising in Korea is 5,428 thousand tons in 2016, which consist of 4,344 thousand tons of domestic products and 1,084 thousand tons of imported products. The cultivation area of the forage is 272 thousand hectares, while the self-sufficiency rate of the forage is 80% (MAFRA, 2015). Domestic grassland area is maintained at 35,000 ha, while grassland area decreases yearly.

Types of forage used mainly in Korea include rice straw, whole crop wheat and maize silage. The forage is mainly made in the form of a round bale wrapped with a plastic stretch film, and commercially sold. Rice straw is dried on the rice field after grain harvest and stored in round bales until sold. However, forages such as wheat, barley, maize and

Italian ryegrass are hardly dried on the field, and bailing is completed without hours after harvesting.

According to the results of the quality inspection conducted on round bales in 2016, the overall quality improved from the C grade in 2015 to B grade in 2016 through the increasing production of haylage and hay. Distribution of quality grade in 2016 indicated, A, B, C, D, while E were 63.4, 22.7, 6.7, 5.2 and 2.0%, respectively. This result indicates high production of good quality rice bales for domestic market. However, some improvement in moisture content measurement method is necessary for accurate quality estimation of bales. The harvesting time is very limited in the cultivation of double-crop, thereby resulting in

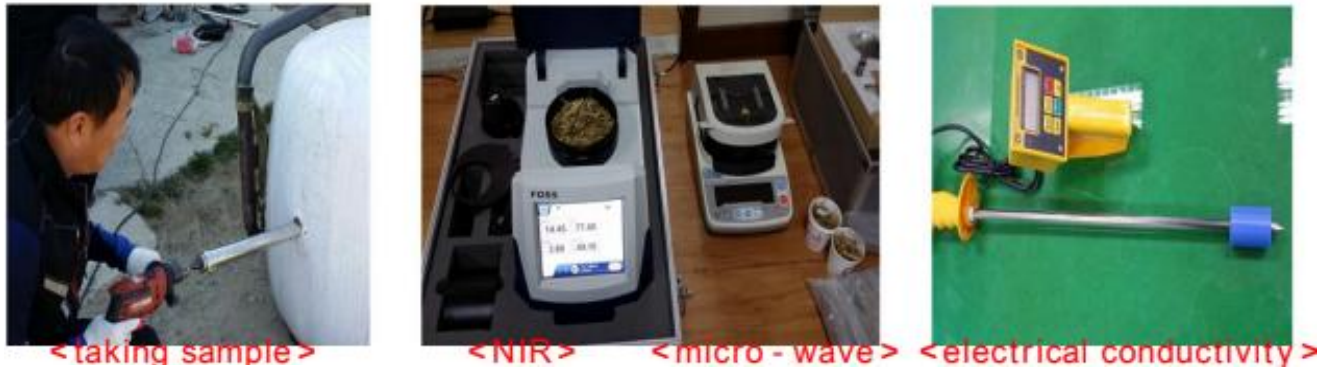


Figure 1: Figure of sample collection and analysis.

poor quality in the production process; the harvesting operation proceeds with the moisture content of the crop being very high, which causes the quality of the forage to deteriorate.

Because current Korean forage is marketed based on DM content, it is important to determine moisture content in stored forage. Accurately measuring forage moisture concentration requires that the forage be oven-dried under controlled conditions. This is a time consuming process that is usually performed in the laboratory. However, good estimates of forage moisture concentration can be made quickly and easily on the farm using various methods. Currently, when we carry a bale, we weigh the weight of the bale by measuring the weight of the bale in the vehicle, but in the case of moisture content, it is necessary to collect the sample and analyze it (Chambliss, 2002; Garthe, 1990 a, b). In the case of round bales, it takes time and effort to collect samples from the bale for moisture content analysis. In addition, even when the hole is pierced, deterioration of the internal forage is caused by the inflow of outside air as a result of the sealing portion being damaged due to sunlight (Park, 1984).

Farmers who produce forages have knowledge of the quality of forage produced, but in the case of livestock farmers who purchase and use the forage, the quality of the forage cannot be known without unpacking the wrapped package. Therefore, this study was carried out in order to develop a method to effectively confirm the internal moisture content of the round bale wrapped with plastic stretch film in the field.

MATERIALS AND METHODS

Forage harvesting and utilization methods

To investigate the harvesting and utilization methods of forage, livestock farms and TMR feed processing plants were surveyed using forage. The survey was conducted by visiting the site directly. Based on the survey on the usage of forage,

an effective mechanization method for the production of forage was established.

Comparing of moisture content by various measurement methods

Having the knowledge of forage moisture is essential for proper harvest and storage management, and for fair marketing. There are several subjective, physical, chemical, and instrumental methods for determining forage moisture. In order to investigate the accuracy of moisture content measurement by the measuring method of forage moisture content, an electric conductivity sensor (HMM-1110, DRAMINSKI), a microwave drying method (MX-50, A and D), and a near infrared ray spectroscopy method (DA1650, FOSS) were used. The electrical conductivity method recorded the moisture content value displayed after the probe was pushed into the round bale. The microwave drying method and the near infrared ray spectroscopy was performed by collecting samples from a round bale using a sampler and analyzing the samples (Hunt, 1989; Jackson, 1993). Analysis was performed for five replicates per sample.

Moisture content measurement accuracy was analyzed by the method of measuring the moisture content of the forage. The most accurate method of moisture content measurement involves taking a sample of the forage and oven dry, but this method takes a lot of time. Therefore, it was analyzed using the NIR and electric conductivity method as a method that can be directly measured and analyzed in the field. The types of investigated specimens were whole wheat, maize and rice straw round bale. **Figure 1** shows the equipment used for sample collection and analysis of the round bale. All methods were analyzed by 5 repetitions.

Moisture content spatial distribution of round bale

The spatial variation of the moisture content of the round bale covered with the plastic stretch film was analyzed. For

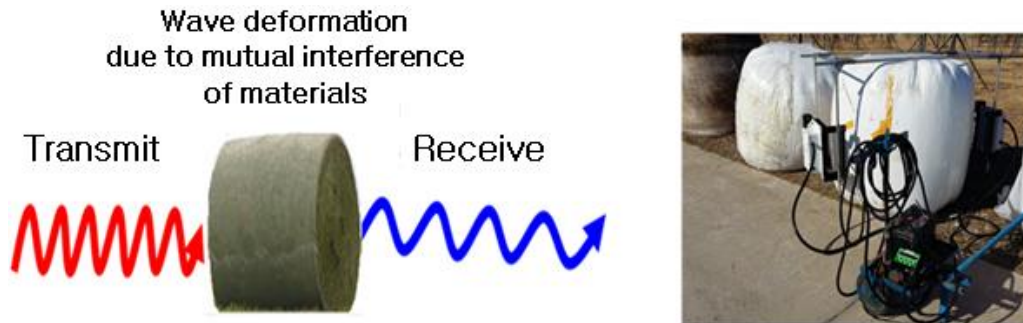


Figure 2: Principles and test figure of moisture content measurement using microwave.



Figure 3: Moisture content measurement test using electrical resistance method.

this purpose, 9 samples were taken from each round bale. The analysis was repeated thrice for each sample using the dry oven method and expressed as an average value.

Moisture content measurement using microwave

The microwave moisture content meter used to measure the moisture content of hay in foreign countries was improved to analyze the moisture content measurement ability of the round bale. Microwave moisture content analyzer measures the moisture content by analyzing the attenuation value of the microwave of the transmitter through the receiver. The sensor used was a GAZEKA (Fine Twine Co.) microwave transceiver. A round bale was placed between the transmitter and the receiver and the receiver value was analyzed. Figure 2 shows the principles and test figure of moisture content measurement using microwave.

Moisture content measurement using electric resistance method

The moisture content of the round bale was measured using the electrical resistance method. The electrical resistance

method was analyzed using the difference of the electric resistance value according to the change of the moisture content. The electric resistance sensor used was PAC40 (Gordon). Figure 3 shows the moisture content measurement test using the electric resistance method.

RESULTS AND DISCUSSION

Forage harvesting and utilization methods

At present, the general usage of the forage utilization method is composed of work steps such as cutting, binding, lapping, storage and feeding. In the case of using rice straw as forage, it is classified into a method of using rice straw after harvesting rice combined, a method of using it as silage of raw rice straw, and a method of using it after completely drying it in rice field. In the case of grasses such as Italian Ryegrass, a method of preparing a round bale after cutting and drying, and a method of preparing a round bale in a raw state without drying. In all the methods, immediately after preparing the round bale, the round bale is covered with 4 to 6 layers using a plastic stretch film, sealed without external air, and stored and distributed. Figure 4 shows the forage mechanized utilization methods in Korea.



Figure 4: Forage mechanization utilization methods.



Figure 5: Self-propelled integral harvester utilization methods.

Table 1: Moisture content analysis of wrapped round bale.

Variable		MWD	NIR	CD	RCD
Whole crop silage of barley	Average	52.0	48.3	34.0	53.1
	Standard deviation	±5.6	±2.3	±11.8	±4.1
Maize	Average	70.8	70.7	-	73.4
	Standard deviation	±3.7	±2.7	-	±3.9
Rice straw	Average	27.4	25.7	52.4	26.2
	Standard deviation	±6.5	±5.5	±11.6	±3.2

*MWD (Microwave drier), NIR (Near infrared), CD (Conductivity), RCD (Revised conductivity).

In the case of maize silage, in the past, it was mainly used after storing fermentation in bunker and tower silos, etc. Recently, however, a self-propelled harvester was developed and used. This system has a method of cutting, collecting, binding and packaging in a separate machine, and simultaneously performing cutting, collecting, binding and packing operations. This system is expected to expand in the future as it has a greater labor saving effect than the conventional method. This method has the advantage of less harvesting loss because it is not subjected to drying process. However, it is necessary to prepare cut and round bale by measuring and analyzing the appropriate moisture content, so that forage having excellent fermentation quality can be produced. Figure 5 shows the self-propelled integral utilization methods.

The order of consumption of the round bale in the

farmhouse or the TMR processing center is first used in the form of first-in-first-out use. Therefore, it is important to store the forage in a stable manner without changing the quality during the long storage period. TMR feed mills are required to purchase a large quantity of round bales from various farms and prepare the necessary TMR feeds while storing them. Hence, it was required that the quality of the round bale should be constant when purchasing it. However, it has been found very difficult to maintain the quality of the forage.

Moisture contents by various measuring methods

Table 1 shows the moisture content according to the type of wrapped round bale. Heat-type or oven-drying type methods

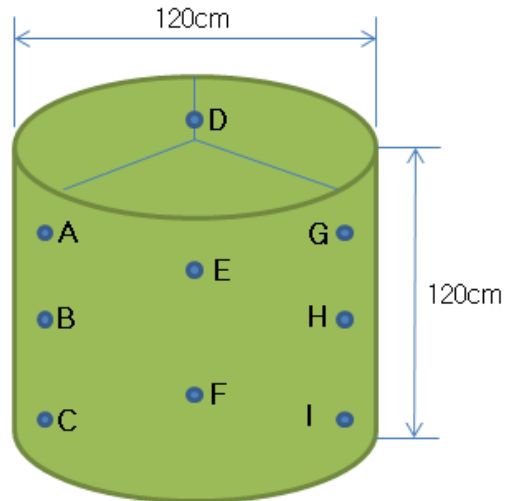


Figure 6: Sampling location for analysis of round bale moisture content distribution.

provide good estimations of moisture content, but require at least 25 min to 24 h of operation. Compared with the moisture content value measured by microwave drying, the NIR method showed a difference of 3 to 4%, while the electrical conductivity method showed a difference of 18 to 25%. In the case of the electrical conductivity method which modified the sensor insulation part, it was 1 to 2% difference. The electrical resistance of the forage is measured between two metal contacts at the tip of the probe when inserted into the round bale. It was concluded therefore that the NIR method and the electric conductivity method can be reliably used as the moisture content measurement method of the round bale. A large difference in the moisture content of the electrical conductivity sensor was judged to be due to a current leakage between the anode and cathode. Electronic conductivity method provide an instantaneous moisture content reading but the readings are often less accurate than those of the heat-type moisture methods.

Moisture content distribution of wrapped round bale

In the case of a round bale, it is a common idea that moisture will move in the bale due to the passage of time after the bale, resulting in the equilibrium of the moisture content as a whole. In order to confirm whether this phenomenon actually occurs, samples were collected by the type of the forage and location as shown in **Figure 6**, and moisture content was analyzed. Samples were taken at 9 locations per each wrapped round bale. The collected samples were transferred to a laboratory in a zipper bag and then averaged by repeating the measurement thrice using a microwave moisture content meter. Four types of forage, whole crop silage of barley, maize and Italian Ryegrass (IRG) were analyzed, and three each of the forage bale were analyzed.

Table 2 shows the moisture distribution characteristics of the wrapped round bale. In the case of the samples measured in the same round bale, the difference of the moisture content was found to be in the range of 2.5 to 23%, indicating that the moisture content balance in the bale was not achieved even after a long time. In addition, it is considered that the method of collecting and analyzing the samples is important because the difference of the moisture content depending on the position may occur depending on the round bale.

Moisture content measurement using microwave

A test system using permeable microwave principle for the measurement of moisture content of forage in foreign countries was made and the possibility of moisture content measurement of the round bale was tested. When a microwave is emitted from one side of a round bale and the receiver is installed on the opposite side, a microwave emitted from the microwave is transmitted through a wrapped round bale, and a waveform change occurs due to mutual interference with the moisture content of the round bale material. Test results showed that the difference between the moisture content value measured by the drying oven method and the output value from the sensor was too large. It was reported that the output value fluctuated severely when it was repeatedly measured in the same round bale, such that it could not be used for moisture content measurement of the round bale.

Moisture content measurement using the electrical resistance method

If there is a difference in moisture contained in the forage, there will be a difference in the electric resistance value.

Table 2: Moisture content distribution of wrapped round bale (unit: %).

Variable	S/NO	A	B	C	D	E	F	G	H	I	Av	SD	Maximum	Minimum	Df
Tall fescue	1	18.5	19.0	18.9	19.4	18.2	20.7	19.4	19.6	20.4	19.3	0.8	20.7	18.2	2.5
	2	47.2	43.7	47.0	39.1	47.0	45.6	53.0	49.2	46.4	46.1	3.8	53.0	39.1	14.0
	3	39.2	56.7	56.7	36.0	48.1	41.3	40.9	53.5	58.9	47.9	8.8	58.9	36.0	23.0
Whole crop silage of barley	1	60.7	59.8	54.4	55.9	56.8	58.7	55.4	58.1	53.9	57.1	2.4	60.7	53.9	6.8
	2	51.0	48.8	56.1	48.6	47.4	54.1	46.4	46.4	47.0	49.5	3.5	56.1	46.4	9.7
	3	59.9	59.1	58.2	61.1	57.6	56.4	57.0	63.7	60.2	59.2	2.3	63.7	56.4	7.3
Maize	1	62.1	61.1	65.5	64.8	66.1	65.3	64.6	63.6	63.2	64.0	1.7	66.1	61.1	5.0
	2	61.3	62.3	62.8	63.2	61.7	65.9	64.2	62.5	64.6	63.2	1.5	65.9	61.3	4.6
	3	57.6	56.1	58.2	57.4	62.9	60.6	60.2	58.9	60.1	59.1	2.1	62.9	56.1	6.8
IRG	1	49.6	43.7	38.9	43.8	40.1	36.8	46.9	42.0	38.5	42.2	4.2	49.6	36.8	12.8
	2	40.6	40.1	38.3	58.6	41.5	39.2	38.4	40.7	46.6	42.7	6.5	58.6	38.3	20.3
	3	43.2	46.7	59.4	52.7	51.5	43.6	40.2	51.4	49.0	48.6	5.9	59.4	40.2	19.2

* Av (Average), SD (Standard deviation), Max (Maximum), Min (Minimum), Dif (Difference between maximum and minimum).

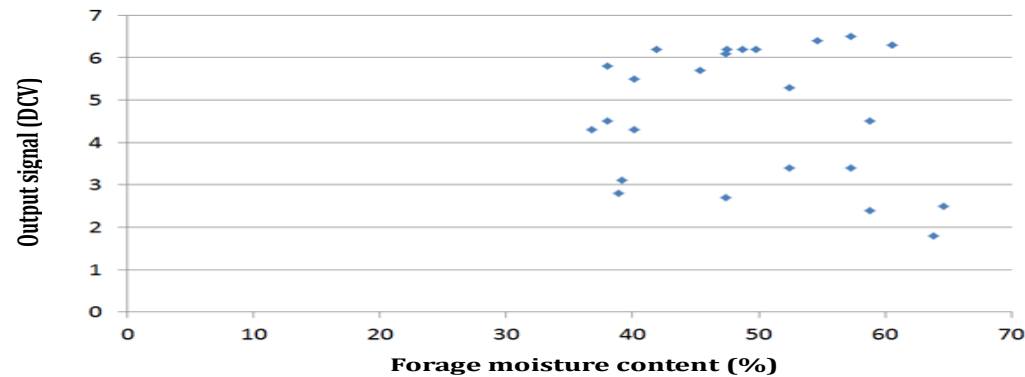


Figure 7: Changes in moisture content and output value of a round bale.

That is, when the moisture content of the forage mass is large, the electric resistance value becomes large. On the contrary, when the moisture content is small, the electric resistance value becomes small. Using this principle, a technical test was conducted to determine whether the moisture content of round

bale forage can be measured non-destructively. The electric resistance value was measured by contacting the electric resistance sensor on the round bale. At the same time, a sample of the forage was collected from the same location using a forage sample sampler; and the moisture content was analyzed

using a drying oven method. The moisture content was analyzed by the oven drying method and the measured electrical resistance compared with the moisture content.

Figure 7 shows the change of the output value was analyzed by attaching the sensor to the wrapped

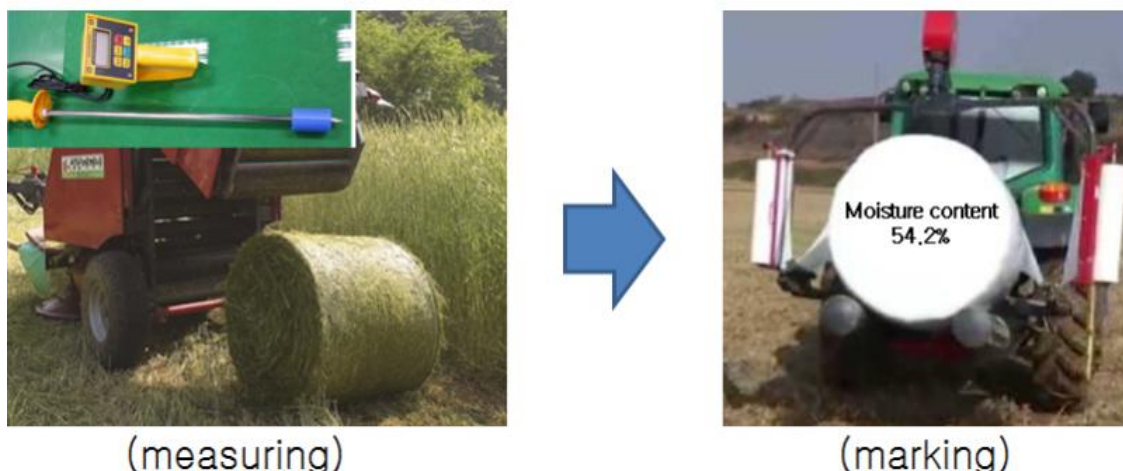


Figure 8: Effective method of moisture content measurement of a round bale.

round bale. As a result, the measured value at the same position showed a very large change in the output value depending on the method of contacting the sensor and the change of the force applied to the sensor.

Efficient method of moisture measurement of Round Bale forage

Round bales are mostly supplied to farmhouses after wrapping. To measure moisture content, drilling a hole in a wrapped round bale, taking a sample and using the dry oven method takes a lot of effort and time. For the sampling, the pierced part is easily detached by the sunlight even if it is sealed with tape. Therefore, when the outside air enters the wrap covering bale through this hole, there occurs a change in the quality of the forage from the part, and the bale may eventually be damaged. The moisture content of the round bale can be determined by the electric conductivity method before the plastic stretch film is wrapped, and the moisture content of the round bale can be immediately detected on the spot. As previously analyzed, the content of moisture is very large in the same round bale depending on the sampling position. To accurately measure the moisture content of a round bale, it is necessary to measure the moisture content of many places, such as the edge of the round veil, and the center etc. The average value of the moisture measured in several places is expressed as the moisture of the round bale.

Glen and Ron (2004) suggested that samples should be collected randomly from 12 to 20 sites to accurately measure the moisture content of the forage. This method is economically feasible because it requires almost less analytical cost since it is possible to confirm the moisture directly in the field as compared with the method of analyzing by the drying oven method in the laboratory. The electrical conductivity method is a tool with which a

producer can estimate moisture content of a forage and has the advantage of allowing several samples to be done quickly.

Conclusions

The moisture content of the round bale was measured and analyzed by various methods such as electrical conductivity, microwave and electrical resistance. Heat-type or oven-drying methods provide good estimations of moisture content, but requires 25 min to 24 h of operation. However, electrical conductivity method provided instantaneous moisture content reading, but the readings are often less accurate as compared to those from heat-type moisture methods. Even within the same round bale, the variation in measured moisture content was large depending on the sampling spots. Therefore, in order to accurately measure the moisture content of the round bale forage, it is important to measure the moisture content in a measurable manner immediately after the preparation of the round bale and then wrap it with the plastic stretch film.

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