

## MEASURING MOISTURE IN HAY

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### ABSTRACT

Knowing forage moisture is essential for proper harvest and storage management, and for fair marketing. Basic protocols are described for several methods of determining moisture. Drying ovens and heat-type moisture testers tend to be more accurate than electronic conductance moisture testers, although results can be affected by many factors, including the effects of hay-drying agents. The electronic probe is not a "magic box", but a tool with which a producer can estimate moisture of hay. The electronic probe has the advantage of allowing for many samples done quickly. The following methods are ranked from most to least accurate with error enclosed within parentheses: 1) convection oven drying ( $\pm 1\%$ ); 2) microwave oven drying (-2 to +1); Koster tester and near infrared reflectance spectroscopy, NIRS, ( $\pm 3\%$ ); and 3) electronic probe ( $\pm 5\%$ ). Moisture is not uniform in windrows, bales, or stacks. Regardless of the procedure used, 12 to 20 random samples are necessary to accurately determine forage moisture.

**Keywords:** Alfalfa, hay moisture,

### INTRODUCTION

Forage harvested for hay should be sampled to determine moisture before raking or tedding, before baling, and in the stack. Knowing forage moisture is essential for proper harvest and storage management, and for fair marketing. Knowing forage moisture is critical for choosing if and how much of preservative to use for minimizing harvesting and storage losses, and in predicting effects on forage quality.

There are several subjective, physical, chemical, and instrumental methods for determining forage moisture. All methods depend on proper forage sampling. Because only a small quantity is sampled, it is important that the sample be representative of the entire lot of forage. This paper describes forage moisture, how it is determined, and how to sample for estimating forage moisture in the windrow, bale, and stack.

### TYPES OF MOISTURE

Moisture, or water, occurs in three forms: free water, physically trapped water, and bound water. The free water can be readily evaporated from the forage. The physically trapped water is contained inside plant cells. The free and physically trapped water can be evaporated from the forage given proper solar radiation, relative humidity, and time. One merely needs to monitor

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the moisture level to determine when to rake, ted, or bale at the correct moisture. At baling time, the moisture content is critical for the retention of leaves to the stem, but too much moisture in or on the plant is a hindrance to storage. Moisture necessary for leaf retention can come in two different types:

**Stem moisture** remains in the plant stem during the curing process. Windrowed hay, given ample time to field-dry, will eventually dissipate stem moisture.

**Dew moisture** on the outer surface of the stem and leaf is caused by the relative humidity and condensation. Dew moisture is rapidly removed by sunlight or a light breeze and usually only remains for a few hours each day. It is important to recognize the moisture level in windrowed alfalfa at baling time because high moisture levels will cause molding in the stored product, and, in many instances, internal combustion and hay stack fires.

## DRYING METHODS AND EQUIPMENT

A number of methods are available for drying forage samples. One must remember that taking an individual sample from one location in the field, windrow, stack, or silo is not adequate, and will not reveal the moisture level across the entire lot of forage. Similar to testing for quality, where twelve to twenty samples from each lot of hay are recommended, it is suggested that numerous random samples be taken across the entire source of forage. Twelve samples may be adequate in forage with uniform dryness, but 20 samples are necessary under variable conditions.

### *Laboratory Drying:*

Wet samples can be taken to a local forage-testing laboratory for testing moisture content as well as forage quality. Gravimetric or near infrared reflectance spectroscopy (NIRS) lab methods are very accurate; however, lab methods requires about one day for results to be returned to the producer, and because of this time lapse the window of opportunity for correct baling moisture may be lost.

### *Microwave Drying:*

Microwave oven drying is fast and efficient; however remember the number of samples necessary to insure accurate representation of the entire lot of forage. Also if your kitchen microwave is used and a sample is over-dried, the smell may linger for several days. Over-drying can cause dry matter loss or burn the sample, which gives a false moisture content. Place a glass of water 2/3 full in one corner of the microwave oven to avoid over-drying, and closely monitor the sample as it is quickly drying. The sample size should be between 4 and 12 oz (100 and 300 grams). Drying time depends on the power setting on the microwave, the mass of the sample, and the moisture content. Begin by using short drying periods -- 2 minutes for haylage, silage or fresh material; 1 minute for dry hay. As experience with an individual microwave and forage increases, adjust times accordingly. Mix the forage, rotate the container, and return it to the microwave. Reweigh the sample and dry for 30-second to 1-minute increments until the dry weight remains stable. Continue drying for 30 seconds if forage is nearly dry, one minute if still moist. If the forage gets too hot to mix comfortably by hand, use a lower power setting until forage is nearly dry.

### ***Convection Oven Drying:***

Large industrial convection ovens are very desirable for drying numerous forage samples, allowing for ample samples to be taken. The operator must plan on allowing at least twenty-four hours of drying time for adequate moisture removal of numerous samples. The largest draw back to the industrial convection oven will be in the cost of purchasing the oven for private use. Samples of 100 to 300 grams should be dry after 24 hours at 140-150°F (60-65°C). Samples dried at higher than 150°F (65°C) should not be used to determine forage quality. Always check samples for dryness by feel and checking for weight loss after 1 hour further drying.

### ***Koster Field Drier:***

The Koster field drier is a versatile, easy to use, accurate, and inexpensive forage drier. An electrical source or portable generator is necessary. This unit operates on a flow of warm air forced by a small fan up through the forage. The Koster kit comes complete with weighing scale, drying container and the drying unit. The Koster drier will dry individual 100 gram samples (0.22 lb) in approximately 30 minutes, allowing for numerous samples to be dried in one day. One drier may not be adequate for producers with over 500 acres of hay.

Preparing samples to be dried in a Koster is very similar to the microwave oven method. The major difference is that the Koster scale is calibrated differently. Follow these steps:

1. Adjust the pointer on the scale dial to read 100 percent in black and 0 percent in red by turning the knob beneath the platform.
2. Place chopped forage into the drying container until the pointer reads 0 percent in black and 100 percent in red.
3. Place drying container with sample in the Koster and run for about 20 minutes.
4. Weigh sample and read moisture content in black and dry matter content in red, as indicated by the pointer on the dial.
5. Continue to dry for five minute intervals and reweigh until there is no further change in scale reading from the previous weighing.

**TIP:** If exactly 100 grams of forage was weighed onto the plate, the final dry weight (minus the paper plate weight) subtracted from 100 is the moisture content. Alternatively, the final dry weight is the dry matter percentage.

### **Example:**

Original wet weight was 100 grams. Final dry weight is 55 grams.

$$100 - 55 = 45\% \text{ moisture content or } 55\% \text{ dry matter}$$

Information on Koster kits can be obtained from Koster Crop Tester, Inc., 23317 (Rear) Pearl Road, Medina, Ohio 44256-8339

## **ELECTRONIC MOISTURE TESTERS**

Most probe-type meters operate on the principle of electrical resistance, utilizing the relationship between the moisture content of the material and its conductivity. This relationship is possible because moisture is an effective conductor of electricity and hay acts as an effective insulator. The "reading" is made between the two metal contacts at the tip of the probe. The wetter the hay, the more electricity flows through. There are two basic types: hand-held probe and chamber mounted. The chamber-mounted types enable the operator to monitor moisture on a continual basis from the tractor seat. They are virtually standard on large rectangular balers and are also available for large round and small balers.

Electronic moisture testers are an excellent tool, but they are subject to error. Hay can gain or lose 3-5 percentage points of moisture in an hour, and there can easily be 10 percentage points of variation in a windrow. Accuracy is affected by bale density, the type of forage, whether it is plant moisture or dew moisture, and whether acid preservative has already been applied. Electronic moisture testers need to be calibrated to the conditions and well maintained. Accuracy also depends on having a well-charged battery in the probe. Ambient temperature also affects accuracy of the electronics, but forage contact bridging the brass parts of the tip, a charged battery, and clean brass on the probe are much larger sources of error. The brass contact points need to be occasionally cleaned with some steel wool. Don't let digital readings give you a false sense of accuracy. Moisture testers should be used as a tool to supplement personal experience when checked with other methods.

Greatest "accuracy" can only be obtained when the moisture tester is used on samples which are close to average samples on which the basic meter calibration was developed. Some of electronic probes list a range from 8 to 40% moisture. The range of accuracy listed by one manufacturer is from 20 to 80%. Read the specifications for your moisture meter.

Since there is no way to duplicate such conditions when using the meter in the field, and since field conditions can change rapidly, accuracy guidelines must be considered in terms of "ranges", not specific points. Identical meters or the same meter read by another person may yield different results, depending on the persons's sampling procedure, conditioning and uniformity of the samples, difference in crop, and differences in oven test procedure.

The primary, or electrical calibration of the tester can easily be checked by using a resistance standard supplied by the manufacturer, or by the battery/calibration checkpoint which is built in to some models.

One manufacturer of electronic bale moisture probes have a forked probe designed to sample moisture from windrowed alfalfa compressed into a container. A limiting factor to this method of moisture detection has been the lack of adequate compaction of the windrowed alfalfa. High density of the forage is necessary to ensure proper contact between the two brass portions of the electronic bale moisture probe and the moist forage. We recommend alfalfa producers sample windrow moisture by using an electronic bale moisture probe and a windrow-sampling tool. The windrow-sampling tool is designed to simulate the compaction of hay in the bale, in addition, the sample may be oven dried to check probe accuracy.

Probe estimates often are inaccurate when dew forms on dry hay. Because electronic probes measure the resistance or conductivity of electricity in the hay, a small increase in moisture on the surface of the hay may increase conductivity dramatically. This increase due to surface moisture results in the meter over estimating forage moisture.

### *Moisture and Temperature Probe Listing*

**FARMEX:**

1205 Danner Drive  
Aurora, Ohio 44202  
Phone: (800) 821-9542

**DELMHORST:**

Delmhorst Instrument Co.  
Marketed by Lehman Brothers  
19164 Briedwell Road  
Amity, Oregon 97101  
Phone: (503) 434-1705

### **CALCULATING FORAGE MOISTURE**

Forage moisture content is calculated by the following formula:

$$\frac{(\text{wet forage weight} - \text{dry forage weight})}{\text{wet forage weight}} \times 100 = \text{percent forage moisture}$$

**Example 1:** An 8-oz sample weighed 6-oz when dried.

$$\begin{aligned} \text{Moisture content} &= (8-6)/8 \times 100 = 25\% \\ \text{The dry matter content} &= 100\% - 25\% = 75\% \end{aligned}$$

**Example 2:** Original wet weight is 100 grams. Final dry weight is 55 grams.

$$\begin{aligned} \text{Moisture content} &= (100-55)/100 \times 100 = 45\% \\ \text{The dry matter content} &= 100\% - 45\% = 55\% \end{aligned}$$

This calculation for “as fed” or fresh forage is useful to livestock producers and nutritionists in ration formulation. In contrast, soil water content is calculated as the ratio of (wet - dry) relative to the dry soil. The forage dry matter content is then calculated as (100 – moisture content).

## COMPARISON OF METHODS

**Table 1.** The on-farm and laboratory methods for determining hay moisture content are compared in this table. Adapted from: Forage Moisture Determination. 1993. R.E. Pitt (ed.) Northeast Regional Agricultural Engineering Service, NRAES-59. Ithaca, New York.

Method	Operating principle	Moisture range (%)	Sample size (grams)	Testing time	Typical error (%)
Microwave oven	Drying	15-100	50-200	5-15 minutes	-2 to +1
Koster tester	Drying	20-90	100	30 minutes	±3
Electronic probe	Electrical conductance	8-40%	Bale or windrow	1 minute	±5
Convection oven	Drying	0-100	10-1,000	5 hours – 3days	±1
NIRS	Electromagnetic properties	0-40	1-5	1 hour	±3

## FORAGE SAMPLING

### *Moisture Sampling in the Windrow*

The determination of forage moisture content in the windrow is often a neglected but critical step in the preservation of high quality hay. We recommend alfalfa producers sample windrow moisture by using an electronic bale moisture probe and a windrow-sampling tool. The windrow-sampling tool is designed to simulate the compaction of hay in the bale, in addition, the sample may be oven dried to double check probe accuracy. See proceedings papers in 2002 and 2003 by Ron Thaemert: [http://ucanr.org/alf\\_symp/index.htm](http://ucanr.org/alf_symp/index.htm). And from the Resource for Idaho site: <http://info.ag.uidaho.edu/Catalog/catalog.html> select the **CALS Publishing Catalogue**, then enter alfalfa into the search box, select **Sampling the Moisture Content of Alfalfa in the Windrow: A New Tool Helps**, 2003 CIS 1107

Alfalfa swathed on the same day, in different fields, or in random locations even in the same field may dry at various rates. The following factors affect windrow drying time and should be taken into consideration prior to raking and baling.

1. Maturity of forage at harvest: more mature forage seems to dry faster than immature forage.
2. Low and high elevation areas within a field: ridges usually dry faster because of wind and less dew.
3. Quantity, density, and size of the windrow: large and dense windrows will dry more slowly than smaller less dense windrows.

4. Soil moisture retention under the windrow: the higher the soil moisture under a windrow, the slower the drying. Irrigation within one week of harvest can cause soil compaction, and drying time is increased by placing a wet forage windrow on wet soil.

### ***Forage Moisture Estimation Methods***

While the time-honored methods for determining hay moisture content--the thumbnail test and the twist test--are useful as a check, proper use of an electronic forage tester will minimize some of the guesswork involved in the challenging science of baling hay at optimum moisture content. The concept of "I see my neighbor going to bale his hay and I cut mine the same day, so it must be ready" is a misconception and is unreliable. The other popular method of twisting and breaking the stem is useful if you wait until the stem actually breaks however by then the forage is too dry and leaf retention is almost impossible to maintain until dew occurs.

Producers need to sample hay in windrows for moisture content to avoid forage quality degradation or haystack losses due to fire. Samples taken from the windrow sampling tool should be oven dried to determine the accuracy of the hay moisture probe being used.

Remember the following points to assure even representation of the entire field when sampling for moisture:

- Take 12 to 20 random samples
- Test samples from diverse areas of the field
- Take the wettest sample, usually from underneath the windrow
- Oven dry some samples for accuracy test

### ***Bale and Stack Sampling for Moisture and Temperature***

Sampling stacks and individual bales for moisture and temperature is a relatively simple task to perform with a hand-held digital moisture and temperature detector, but is absolutely necessary to assure safe storage of an entire lot of hay.

#### **Procedure:**

1. Insert probe of the moisture/temperature detector into individual bale at least 12 inches.
2. Read digital display for temperature and moisture (allow ample time for probe temperature to adjust in the individual bale), then read temperature and moisture.
3. Remove probe from bale and clean brass tips of probe with fine steel wool.
4. Repeat the above steps in at least twenty random locations for each lot of 200 tons of hay.

### ***Relationship of bale size, moisture levels, and other factors***

It is important to match the correct windrow moisture to the size and density of bales (Table 2).

**Table 2.** Physical characteristics and moisture percentages required for good storage of various bale types, sizes, and densities. These values are rough averages for several major manufacturers. There are usually several models available within each category.

Characteristic	Small	3-string	Mid-size	Large	Round
End size (in)	14 x 18	15 x 22	32 x 32	48 x 48	72
Length (in)	38	44	96	96	60
Volume (ft <sup>3</sup> )	5.5	8.4	56	112	141
Weight (lb)	60	130	900	1800	1900
Density (lb/ft <sup>3</sup> )	8-11	15	14-16	14-16	10-13
Maximum moisture (%)	20	18	16	16	18
Tractor power <sup>1</sup> (hp)	60	80	90	120	70
Capacity (t/hr)	5	10	20	40	10-16
Baler price (\$)	\$15,000	\$25,000	\$37,000	\$75,000	\$25,000
Baler weight (lb)	3,000	7,800	10,700	18,300	6,800

<sup>1</sup>Minimum power required, recommended may be 30-50% more--follow manufacturers recommendations

## CONCLUSIONS

Drying ovens and heat-type moisture testers tend to be more accurate than electronic conductance moisture testers, although results can be affected by many factors, including the effects of hay-drying agents. The electronic probe is not a "magic box", but a tool with which a producer can estimate moisture of a forage. Moisture is not usually uniform throughout. The electronic probe has the advantage of allowing for many samples done quickly. Certainly, a basic protocol should be followed, but in the end, each farmer uses the moisture tester, based on his own experience, to produce quality hay with the management and equipment he uses.

Baling or ensiling forage at the proper moisture concentration can reduce both harvest and storage losses to provide a high-quality feed. Forage moisture concentration can be quickly estimated on the farm using one of three methods: the hand method, moisture testers, or the microwave-oven method. The hand method is fast, but is only a crude approximation of forage moisture concentration. Two types of moisture testers are available to determine forage moisture concentration. Heat-type, or oven-drying, testers provide good estimations of moisture concentration, but require at 25 minutes to 24 hours of operation. Electronic conductance moisture testers provide an instantaneous moisture concentration reading; however, the readings are often less accurate than those from heat-type moisture testers. The microwave-oven method requires approximately 30 minutes and provides relatively accurate results. No matter which method you choose, use 12 to 20 good representative samples of the forage for the best results.

**Disclaimer:** The products mentioned are not a complete list, but are some of the most commonly used moisture testers. Mention of a trade name or proprietary product is not an endorsement of that product over similar units from other manufacturers.