

Storage, Sampling and Measuring

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Storage Units

An economic comparison of the various forage storage units indicated that concrete bunkers were the cheapest method of storage and air-tight silos were most expensive (*Table 1*). Plastic bags were also one of the more inexpensive storage methods for large quantities. Total investment for bagging included the cost of the bagging unit, approximately \$25,000. Leasing the bagging unit

will dramatically decrease the cost, but availability of the unit and expertise in using it must be considered.

Forage Moisture Testing

The most critical aspect in preserving high-quality hay, haylage or silage is the determination of the forage moisture content.

Table 1. Economic comparisons for various forage storage units at two capacities¹

Silo Type and Size	Capacity (tons DM)	Total Investment	Ownership Costs (per ton DM)
metal oxygen-limiting			
20 x 80	200	\$ 82,000	\$67.65
25 x 90	325	113,800	57.77
concrete oxygen-limiting			
0 x 72	170	62,000	60.18
30 x 100	510	120,000	38.82
concrete stave			
20 x 70	155	30,250	32.20
30 x 80	425	52,500	20.38
concrete bunker			
10 x 30 x 185	750	24,800	5.13
12 x 40 x 112	500	23,800	7.38
bagger and bags			
5 bags	250	34,500	32.43
15 bags	750	38,000	11.91

Source: T.D. Hewitt, 1986. Dairy Herd Management 23(12):29

¹ These figures do not take into consideration the differences in forage loss due to spoilage.



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Methods to do this vary widely from producer to producer, with many relying on experience and feel. Without a precise determination of moisture in the forage, poor silage can result or baled hay becomes moldy and unpalatable.

Using proper sampling techniques is essential to obtain a representative sample for moisture determination. For hay, the procedure used will vary, depending on whether sampling is being done from the windrow, bale or stack.

Hay windrow sampling

Windrow sampling should be done from at least three locations in the field. Ideally, a small canvas should be placed under the windrow before a six-inch cross section is cut with garden shears or clippers. If the hay is dry, the canvas will help avoid losing additional leaves. Cut the hay sample into short pieces no longer than two inches and composite in a pail for moisture determination.

Difficulties in gaining a representative windrow sample make this method less accurate than baling 6 to 10 bales and then core sampling them.

Hay bale (stack) sampling

Bale sampling requires the use of a bale probe. When sampling small square bales, take a core from the butt end of the bale. Place the cores in a plastic bag until moisture determinations can be made. Large round bales should be cored from each side and not the flat ends. Compressed stacks need to be sampled from the top to gain a representative sample.

Moisture Determination

Microwave Oven

Silage, haylage or hay moisture content can be evaluated in a microwave oven. This technique is fast, easy to perform and very accurate in determining the precise moisture content of any forage. The major drawback with this system is that an electrical power source is required, which is not always convenient for testing forages. In addition to a microwave oven, a small weighing scale, a paper plate for each sample and a glass of water are needed. The scale is most ideal if it can weigh both ounces and grams, but grams would be the unit of choice. An easy moisture determination method is described below, using a gram scale.

1. Place the paper plate on the scale and note how many grams it weighs. A good suggestion is to write this weight on the edge of the plate. Re-weigh the plate each time it is used.
2. Weigh 50 to 100 grams of chopped forage onto the plate on the scale. Cored samples do not need further chopping.
3. Spread the sample evenly over the plate and place it in the microwave with a half-filled glass of water in the back corner. Silage samples, estimated to be in the 50 to 75 percent moisture range can be heated initially for four minutes. Hay samples with less than 30 percent moisture should only be heated for three minutes.

4. Weigh and record the weight, then stir the forage on the plate and place it back in the oven for one additional minute.
5. Repeat procedure four again, but only run the oven for 30 seconds this time. Continue drying and weighing until the weight becomes constant. Be careful not to heat the forage to the point where it chars. If this occurs, shorten the drying intervals.
6. To calculate the moisture percentage, subtract the last dry weight from the original wet weight and divide this number by the wet weight. Now multiply by 100. This is the moisture content of the sample.

Example:

Original wet weight was 90 grams.
Dry weight is 60 grams.

$$90 - 60 = 30$$
$$(30 \div 90) \times 100 = 33.33\% \text{ moisture}$$

Easy method: 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% dry matter

The following is 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.

Koster Tester

The Koster Crop Tester is easy to use and is a very accurate method of moisture determination. This unit operates on a flow of warm air forced by a small fan up through the forage to be dried. The Koster kit comes complete with weighing scale, drying container and the drying unit. Portability and accuracy are the two positive aspects of the Koster tester. The length of time to completely dry a sample detracts somewhat from its appeal, as hay samples can take up to 30 minutes to completely dry. It also requires an electrical outlet to operate the heating unit and fan.

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 enough chopped forage in 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 weigh until there is no further change in scale reading from the previous weighing.

Information on Koster kits can be obtained from Koster Crop Tester, Inc., 21079 Westwood Drive, Stongsville, OH 44136, (216) 572-5615.

Electronic Moisture Testers

Several electronic moisture-tester probes are available commercially today. These are fast and easy to use; however, their accuracy can be somewhat variable if only one or two readings are taken. It is important to take at least six to eight readings from each

bale and to average the results for the moisture content. Moisture determination by this type of tester is made by measuring the relative electrical conductivity to the probe. Several factors, such as bale density, bale type and type of hay, can influence the moisture reading.

Forage Math

Area Length

1 hectare = 2.47 acres

43,560 square feet = 1 acre

1 kilometer = 0.62 miles

1 meter = 39.37 inches

Volume

1 liter = 0.908 quarts (dry)

1 liter = 1.057 quarts (liquid)

1 gallon = 8.33 lbs water

1 cubic foot = 7.48 gallons

1 cubic foot = 62.4 lbs water

Calculating Acreage

Corn and Sorghum

row length (feet) x row width (inches) x number of rows ÷ 522,720 = acres

Small Grain and Drilled Crops

length (feet) x harvest width (feet) ÷ 43,560 = acres

Converting Forage Yields to a Common Moisture

It is common to adjust forage yields to 65 or 70% moisture so yields can be compared fairly. To do so, the following formula can be used:

Adjusted Yield = (yield (as harvested) x % dry matter (as harvested)) ÷ % dry matter adjusting to

Note: Work with dry matter percent, not moisture percent.

Example A: 21.3 tons of forage at 61% moisture (39% dry matter) is harvested per acre. What is the yield in tons per acre adjusted to 65% moisture?

Yield at 65% moisture (35% dry matter) =

$(21.3 \times 39) \div 35 = 23.7$ tons per acre at 35% dry matter

Example B: What would be the yield adjusted to 30% dry matter?

Yield at 70% moisture (30% dry matter) =

$(21.3 \times 39) \div 30 = 27.7$ tons per acre at 30% dry matter

Example C: What would be the yield adjusted to 100% dry matter?

Yield at 100% dry matter =

$(21.3 \times 39) \div 100 = 8.3$ tons per acre at 100% dry matter

Cubic Feet Per Ton of Feed

Kind of Feed	Length of time in storage	
	30 to 90 days	90+ days
	— cubic feet —	
Timothy hay	640	625
Clover-timothy hay	580	515
Wild hay	600	450
Alfalfa hay	485	470
Alfalfa hay (mobile stack machine)		360
Chopped alfalfa hay (cut $\frac{3}{8}$ lengths)		150
Chopped alfalfa hay (cut $\frac{1}{2}$ " lengths)		260
Chopped alfalfa hay (cut 1" lengths)		300
Chopped alfalfa hay (cut 2" lengths)		370
Silage, corn (bunker silo)		60
Haylage (bunker silo)		85
Regular bales hay		133
Tight bales hay		100
Silage corn (upright silo)		50
Haylage (upright silo)		65
Alfalfa meal		134
Alfalfa, chopped		170
Barley, meal		72
Barley, whole		53
Concentrates, typical		45
Corn meal		53
Corn and cob meal, dry		56
Corn and cob meal, 30% moisture		51
Corn, shelled		
25% moisture		46
30% moisture		51
Corn, ground ear		
24% moisture		52
28% moisture		50
32% moisture		49.5
Linseed Meal		88
Molasses		26
Oats, ground		106
Oats, whole		78
Rye		45
Soybean meal		48
Tankage		63
Wheat, bran		154
Wheat feed, mixed		134
Wheat, ground		46
Wheat, middlings (std.)		100
Wheat, screenings		77
Wheat, whole		34

Metric Conversions

Multiply the left column by the number in the center column to gain the units in the right column.

Imperial Units	Conversion Factor	Metric Units
AREA		
square inch	6.5	square centimeter
square foot	0.093	square meter
acre	0.405	hectare
CONCENTRATION		
percent (%)	10.0	gram per kilogram
parts per million (ppm)	1.0	milligram per kilogram
FLUID		
ounce (fluid)	28.4	milliliter
pint	0.57	liter
quart	1.1	liter
gallon	4.5	liter
LENGTH		
inch	25.4	milliliter
foot	30.4	centimeter
yard	0.91	meter
mile	1.61	kilometer
RATE		
tons per acre	2.24	tonnes per hectare
pounds per acre	1.12	kilograms per hectare
seeds per acre	2.47	seed per hectare
SPEED		
feet per second	0.30	meters per second
miles per hour	1.6	kilometers per hour
TEMPERATURE		
degrees Fahrenheit (F-32)	0.556	degrees Celsius
VOLUME		
gallons per acre	11.23	liters per hectare
quarts per acre	2.8	liters per hectare
pints per acre	1.4	liters per hectare
acre-feet	0.123	hectares-meters
acre-feed	12.3	hectare-centimeters
WEIGHT		
ounce	28.4	gram
pound	0.45	kilogram
ton (2,000 lbs)	0.91	tonne (1,000 kg)

Concrete Silo Capacities for Corn Silage

Diameter and Settled Depth	% moisture			
	40	50	60	70
	tons			
12 x 30	47	54	62	74
12 x 40	66	75	87	103
12 x 50	85	97	111	132
14 x 40	93	106	121	143
14 x 50	121	137	158	185
14 x 55	134	153	175	210
16 x 50	163	184	210	250
16 x 60	200	230	260	300
16 x 65	220	250	280	330
18 x 50	210	240	270	320
18 x 60	260	290	340	390
18 x 70	310	350	400	460
20 x 60	330	370	420	490
20 x 70	390	440	500	580
20 x 80	460	510	580	670
24 x 60	490	540	620	710
24 x 70	580	650	740	850
24 x 80	680	760	850	980
24 x 90	780	860	970	1,110
30 x 80	1,090	1,280	1,480	1,630
30 x 90	1,240	1,480	1,710	1,880

Steel Silo Capacities for Alfalfa Silage

Diameter and Settled Depth	% moisture			
	40	50	60	70
	tons			
12 x 30	37	47	62	89
12 x 40	54	67	88	127
12 x 50	69	87	116	166
14 x 40	75	94	123	177
14 x 50	98	123	163	230
14 x 55	110	138	183	260
16 x 50	132	165	220	310
16 x 60	165	210	270	390
16 x 65	183	230	300	430
18 x 50	171	210	280	400
18 x 60	210	270	350	500
18 x 70	260	330	430	610
20 x 60	270	340	450	630
20 x 70	330	410	540	760
20 x 80	390	490	630	890
24 x 60	410	510	660	930
24 x 70	490	620	800	1,120
24 x 80	590	730	940	1,310
24 x 90	680	840	1,090	1,500
30 x 80	960	1,180	1,520	2,090
30 x 90	1,110	1,370	1,750	2,390

Adding Water to Whole Plant Corn Silage or Haylage

Initial Moisture %	Desired final moisture (%)					
	56	58	60	62	64	66
	lbs of water to add per ton					
54	91	190	300	421	556	706
56		95	200	316	444	588
58			100	210	333	471
60				105	222	352
62					111	235
64						118

1 gallon of water = 8.33 lbs.

Horizontal Silo Capacities

Depth (feet)	bottom width, feet ¹						
	20	30	40	50	60	70	80
	tons ² per foot of length						
8	3.4	5.0	6.5	8.1	10.0	11.3	13.0
10	4.3	6.2	8.4	10.2	12.2	14.2	16.2
12	5.2	7.5	10.0	12.3	14.6	17.0	20.0
14	6.0	8.7	11.5	14.3	17.0	20.0	22.7
16	7.0	10.0	13.1	16.3	20.0	22.7	26.0
18	8.2	11.1	14.7	18.3	22.0	27.6	29.1

¹ Sidewalls slope out 1 foot in each 8 feet of height.

² Capacity based on 40 pounds per cubic foot. (Approximately 70% moisture silage).

Volumes and Weights of Stacked and Baled Hay

Determining the volume and weight of hay is important whenever hay is sold or yields are determined. Volume of hay is expressed in cubic feet. Weight is expressed in pounds for individual bales, or tons, for stacks and loads. Converting from volume, which is reasonably easy to measure, to weight requires that density (weight per cubic foot) of the hay be measured or estimated.

Stacks

The formula commonly used for estimating the volume of loose hay in stacks is:

$$V = \frac{O \times W \times L}{4}$$

V = Stack volume in cubic feet

O = Average distance over stack in feet

W = Average stack width in feet

L = Stack length in feet

The over measurement (O) can be obtained using a tape or string with an attached weight that is thrown over the stack. The stack should be checked in about four places, then those measurements should be averaged.

Bales

The volume of a stack of baled hay can be determined by measuring length, width and height; then multiplying these together. Another technique used with baled hay is to count the number of bales, then multiply by an estimated or determined weight per bale to determine total weight. The volume of the bales is occasionally needed for storage purposes. With round bales, an estimate of total tonnage can be made by weighing a few bales and counting the number of bales involved.

Weight of hay

The density, or pounds per cubic foot, of both stacked and baled hay varies greatly. The following table gives some guides. It is always better to actually calculate the density after weighing a few bales and determining the volume. It may also be possible to weigh a stack or portion of a stack. Remember that stacked hay settles over time.

	Weight of Loose Hay	Weight of Baled Hay
	— pounds per cubic foot —	
Alfalfa	4 - 5	8 - 14
Grass hay	3 - 5	6 - 10
Straw	2 - 3	4 - 6

Stacking Baled Hay

Figures 1, 2, and 3 (page 7) show how baled hay can be stacked to reduce nutrient loss for small bales when not under cover of a roof.

Today, large round and large squares are the norm, with the latter becoming the standard for dairy operators.

Large squares are designed to fit flatbed trucks to accommodate loading and transportation. Naturally, they require large equipment to handle them.

Large bales still require protection from the weather to preserve maximum quality.

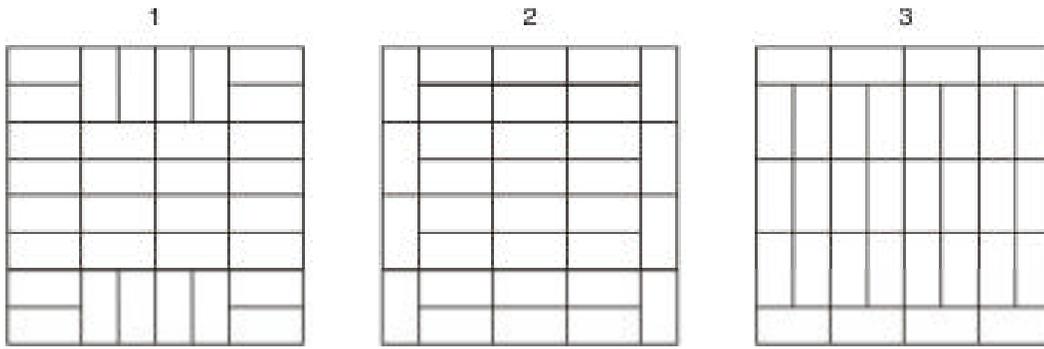


Figure 1.
Layers for stacking
a small square stack
(No. 1 for layers 1
and 4; No. 2 for
layers 2 and 5; No. 3
for layers 3 and 6).

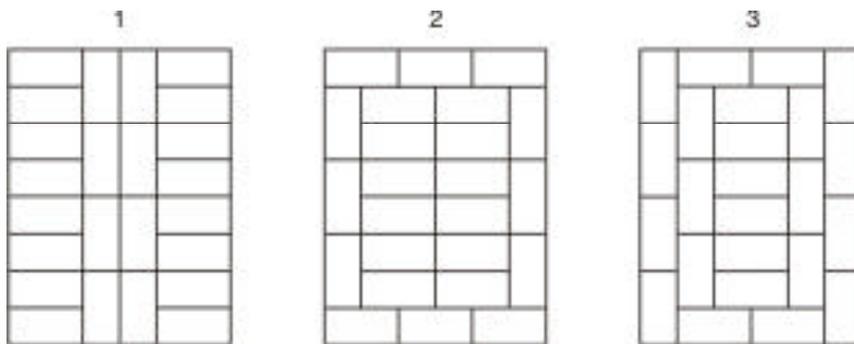


Figure 2.
Layers for stacking
a small rectangular
stack (No. 1, 2
and 3 represent
the same layer as
for illustration A1).

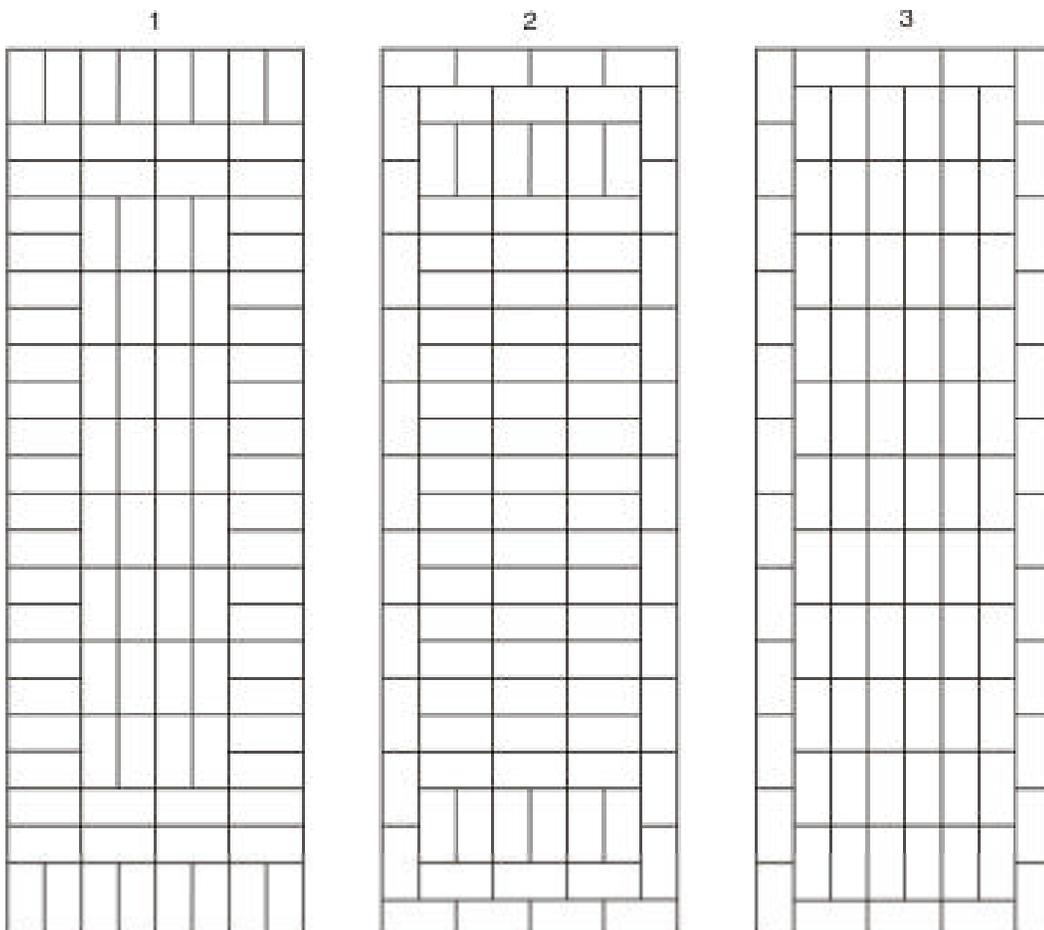


Figure 3.
Layers for a large
rectangular stack
(No. 1 for layers
1, 4, 7 and 10;
No. 2 for layers 2,5
and 8; No. 3 for
layers 3, 6 and 9).

Other publications in the Quality Forage series

- AS-1250 Forage Nutrition for Ruminants
- AS-1251 Interpreting Composition and Determining Market Value
- AS-1252 Haylage and Other Fermented Forages
- AS-1253 Corn Silage Management
- AS-1254 Silage Fermentation and Preservation
- AS-1256 Stressed-Damaged Crops

References

In addition to sources cited, materials were adapted with permission from Pioneer Forage Manual, no longer in print.

For more information on this and other topics, see: www.ag.ndsu.nodak.edu

