AS1255 (Revised)



# 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 also were one of the more inexpensive storage methods for large quantities. The total investment for bagging, including the cost of the bagging unit, is approximately $25,000. Leasing the bagging unit will decrease the cost dramatically, but the 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 capacities[1]

| Silo Type and Size | Capacity | Total Investment | Ownership Costs |
|---|---|---|---|
| | (tons DM) | | (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, handling losses and animal waste.

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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 6-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 2 inches and mix in a pail for moisture determination.

Difficulties in gaining a representative windrow sample make this method less accurate than baling six 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 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. Reweigh 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 be heated for only 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 ÷ 90) x 100 = 33.33 percent 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 percent moisture content or 55 percent 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 versus 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 dry completely a sample detracts somewhat from its appeal because hay samples can take up to 30 minutes to dry completely. 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 the drying container with the sample in the Koster and run it for about 20 minutes.
4. Weigh the sample and read the 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 you see no further change in the 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. These are fast and easy to use; however, their accuracy can be somewhat variable if only one or two readings are taken. You must take at least six to eight readings from each bale and average the results for the moisture content.

The 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 | 1 kilometer = 0.62 miles |
| 43,560 square feet = 1 acre | 1 meter = 39.37 inches |

**Volume**

| | |
|---|---|
| 1 liter = 0.908 quarts (dry) | 1 cubic foot = 7.48 gallons |
| 1 liter = 1.057 quarts (liquid) | 1 cubic foot = 62.4 lbs water |
| 1 gallon = 8.33 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**

Adjusting forage yields to 65 or 70 percent moisture is common 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 percent moisture (39 percent dry matter) is harvested per acre. What is the yield in tons per acre adjusted to 65 percent moisture?

Yield at 65 percent moisture (35 percent dry matter) =
(21.3 x 39) ÷ 35 = 23.7 tons per acre at 35 percent dry matter

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

Yield at 70 percent moisture (30 percent dry matter) =
(21.3 x 39) ÷ 30 = 27.7 tons per acre at 30 percent dry matter

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

Yield at 100 percent dry matter =
(21.3 x 39) ÷ 100 = 8.3 tons per acre at 100 percent dry matter

## Cubic Feet Per Ton of Feed

| Kind of Feed | Length of time in storage: 30 to 90 days | Length of time in storage: 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 ⅜ lengths) | | 150 |
| Chopped alfalfa hay (cut ½″ 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 | bottom width, feet[1] 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|
| (feet) | 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 percent 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** = 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 occasionally is 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 stacked and baled hay varies greatly. The following table gives some guides. Calculate the density after weighing a few bales and determining the volume. Weighing a stack or portion of a stack also may be possible. Remember that stacked hay settles through 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 the cover of a roof. These are seldom used except for small operations or unique cases.

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.

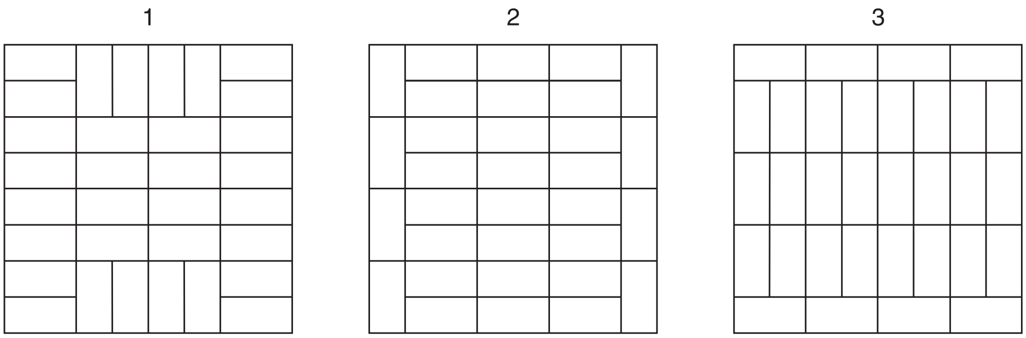


Figure 1.
Layers for stacking a small square stack (No. 1 for layers 1 and 4; No. 2 for layers 2 and 5; No. 3 for layers 3 and 6).

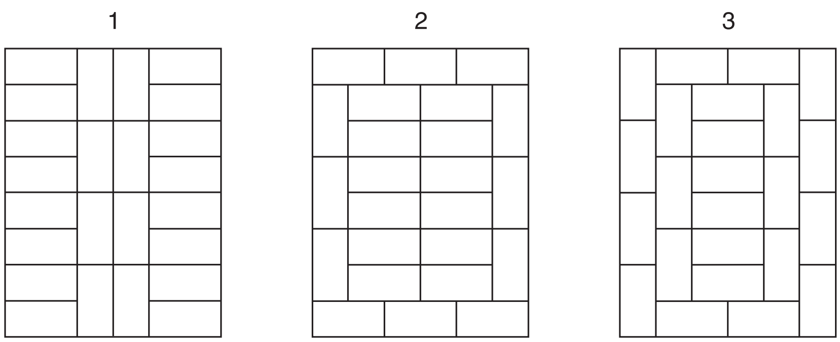


Figure 2.
Layers for stacking a small rectangular stack (No. 1, 2 and 3 represent the same layer as for illustration A1).

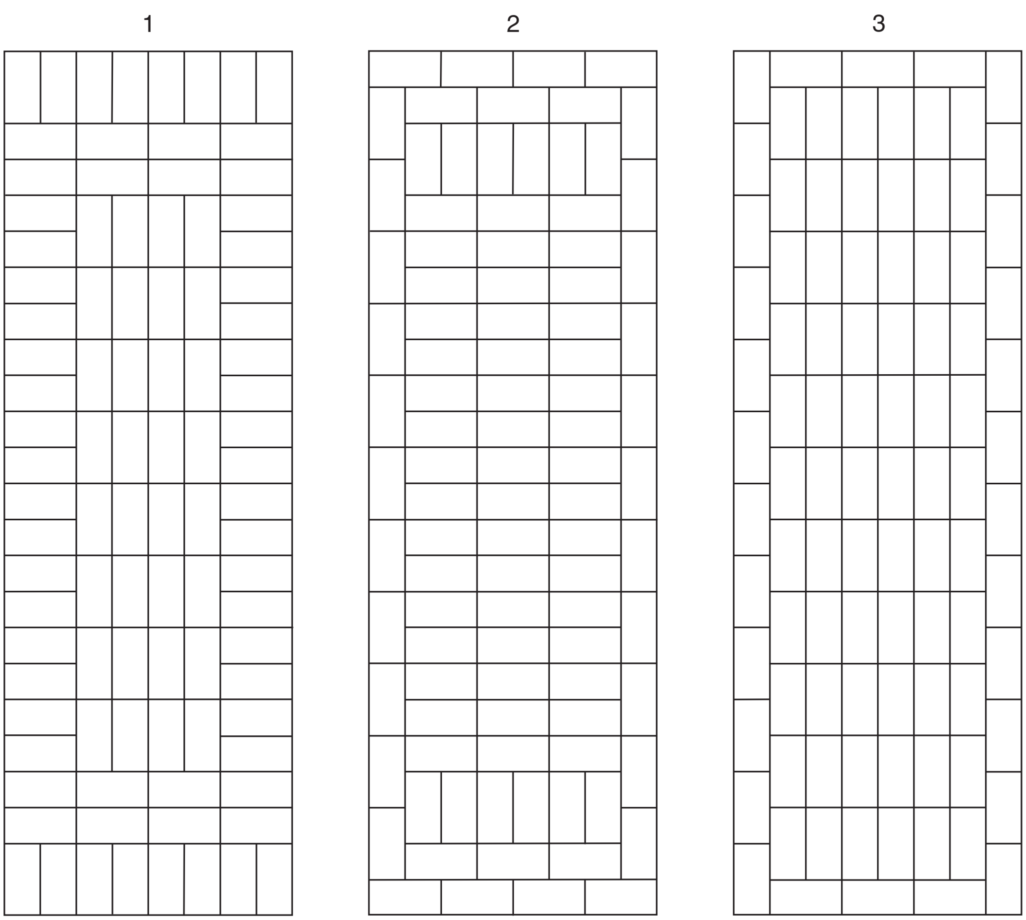


Figure 3.
Layers for a large rectangular stack (No. 1 for layers 1, 4, 7 and 10; No. 2 for layers 2, 5 and 8; No. 3 for layers 3, 6 and 9).

## Other publications in the Quality Forage series

- ➤ AS1250 "Forage Nutrition for Ruminants"
- ➤ AS1251 "Interpreting Composition and Determining Market Value"
- ➤ AS1252 "Haylage and Other Fermented Forages"
- ➤ AS1253 "Corn Silage Management"
- ➤ AS1254 "Silage Fermentation and Preservation"
- ➤ AS1256 "Stressed or Damaged Crops"

References

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

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



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