Everett D. Thomas, William H. Miner Agricultural Research Institute

As livestock farms have increased in size, an increasing proportion of forage crops are being preserved as silage. Even on smaller farms the need for high quality forages is causing farmers to make the shift from dry hay to silage. Harvesting hay crops as silage decreases dry matter losses, reduces the risk of weather damage, and results in forage ideally suited to mechanical feeding systems. The trend to more ensiled forages is expected to continue as new harvest technologies improve corn silage quality and better windrow management of hay crops makes "stem to silo in a day" an achievable goal.

Commonly ensiled forage crops

Corn: More tons of whole plant corn silage are made in the U.S. than of any other ensiled crop. Corn is a high-yielding, high-energy crop, and both harvest and feeding are easily mechanized. In most parts of the US, higher silage yields are possible with corn than with any other forage crop. Genetic improvements are resulting in corn hybrids with higher forage quality, and increased quality testing by both universities and seed companies, are doing a better job of identifying these elite hybrids. Corn is a sugar-rich crop and, therefore, is one of the easiest to ensile. However, all those sugars can pose challenges when the silage is fed out, making management of the exposed surface critical. Fortunately, recent years have seen the development of inoculants containing *Lactobacillus buchneri* that greatly reduce heating on the silage face and in the feedbunk.

"In most parts of the US, higher silage yields are possible with corn than any other forage crop."

Alfalfa, alfalfa-grass, grass-alfalfa and grass (as well as other forage legumes) can be considered together since harvest management of these forages is quite similar. In the Northeastern U.S. over 80% of alfalfa is seeded with a cool-season forage grass,

Table 1: Optimum Harvest Stage and Moisture

CROP	HARVEST STAGE	DM LEVEL %
Corn Silage	½ – ⅔ milkline	32-38%
HMC/Cereals		65-75%
Cereals	boot to dough	35-45%
Grasses	boot	35-45%
Alfalfa:		
Bunker or bag	bud – 1/10 bloom	35-45%
Stave	bud – 1/10 bloom	40-55%
Harvestore	bud – 1/10 bloom	50-65%

while in most other areas alfalfa is seeded alone. Forage crops begin to lose sugars soon after they are mowed, and sugars are the food of fermentation bacteria. The key to high quality hay crop silage is to dry the crop to the proper DM level (Table 1) for ensiling as quickly as possible. Leaving the mowed forage in wide swaths will result in much faster drying and the resulting conservation of plant sugars. Hay crops normally have a lower sugar concentration than corn, so conserving plant sugars is important. Cutting haylage in the p.m. hours after a sunny morning helps to maximize sugar levels. The recommended DM content varies with the storage structure used (Table 1). Face and bunk life is usually less of a problem than with corn silage.

Summer annuals: Millet, sudangrass, sorghum-sudangrass and forage sorghum are all summer annuals that can be ensiled. These are lush crops, with fresh forage DM contents of 12-15%. Wilting is absolutely essential for proper ensiling. Brown midrib (BMR) sorghum-sudangrass hybrids, more digestible than non-BMR hybrids, are lower yielding, but usually result in improved animal performance. Spreading swaths to at least 2/3 of mower width as they are mowed greatly decreases drying time, sometimes to the extent that the crop can be mowed in the morning and ensiled in the afternoon. Because of the high sugar content of these forages, face and bunk management and, therefore, the choice of silage inoculants, is more similar to corn silage than to hay crop silage. In fact, fresh BMR sorghum-sudangrass is often higher in sugar concentration than whole-plant corn.

Small grains: Although there are regional differences in popularity, all of the common small grain (cereal) crops including oats, barley, wheat, rye and triticale are commonly ensiled. Small grain-Canadian field pea mixtures are popular on dairy farms in some parts of the

U.S.: the quality of forage from this mixed crop is usually intermediate between a small grain and alfalfa. The steps necessary for ensiling small grains are similar to ensiling grasses; it's especially important to wilt them to at least 30% DM following mowing, since small grains are notorious for producing smelly, high-butyric acid silage if ensiled at low DM. In some areas, cereal silages are grown as an alternative to corn silage, as an energy crop. In this case the crop is harvested at a more advanced stage with more grain fill, and hence, higher starch levels, and direct cut at a higher DM. Typically, this has been done with wheat, oats or barley, harvested around the soft cheddar stage at a DM level around 40%.

Fresh forage vs. silage

During the ensiling fermentation, bacteria use plant sugars, but they have much less effect on cell walls. Thus fresh alfalfa at 40% NDF will result in alfalfa silage with about 42% NDF.

Table 2: Typical Silage Quality

CROP	% CRUDE PROTEIN	% ADF	%NDF	%30-HR NDF DIGESTIBILITY
Corn	7-9	22-30	38-50	38-50
Alfalfa	18-24	30-40	40-50	40-50
Grass	12-18	30-40	50-65	50-65
Summer annuals	10-16	34-44	55-67	55-67
Small grains	12-17	33-43	50-65	50-65

Silage fermentation also results in a small decrease in DM percentage, usually 1 or 2 units: fresh alfalfa at 35% DM will produce silage at 33 - 34% DM. The following table shows the typical range in silage quality for the most commonly ensiled crops. Note that in most cases there is a wide range in "typical" silage quality. For instance, grass silage at 50% NDF is very high in quality, while grass silage at 65% NDF, while unfortunately all too common, is not. Good harvest management should produce silages that are at the "high quality" end of the range: higher in protein and fiber digestibility, lower in ADF and NDF.

Managing maturity

Corn should be harvested at 30-35% DM. While examination of the kernel milk line is a good start (Figure 4), this is only approximate and should always be confirmed by drying a representative sample of the

Figure 4: Development of Milkline in Corn Kernels (left); Milkline in Corn Ready for Harvest for Silage (right)

crop. To get a representative sample, take about 10 plants per field, hand feed plants from one field through a chipper shredder or chopper and collect a representative field sample of the chopped material. Then subtract about 2 percentage points from the sample dry matter: For instance, if the sample tests 32% DM, it's likely that the field actually is about 30% DM. This is because most samples aren't really representative and are almost always on the dry side. Although this differs slightly between hybrids, the best combination of yield and digestibility is usually at 32-35% DM. Also, silage effluent in bunker silos is greatly reduced at dry matters of 30% and higher.

Alfalfa and most other legumes should be harvested at the late bud stage. A reasonable goal for top quality alfalfa is to never let it bloom. This often results in a harvest interval of 35 days or less, especially between first and second crops. Grasses should normally be harvested at the late boot (preheading) stage. Most forage grasses lose quality very quickly after heading: "When you see the head, the quality is dead." If there is a significant acreage of grass to harvest, all of similar maturity, it may be necessary to start harvest several days prior to the late boot stage. With alfalfa-grass stands, the field should be managed according to the maturity of the alfalfa: when the alfalfa is in late bud stage it should be harvested, regardless of the stage of maturity of the grass. Only when grass represents more than 50% of the stand

should an alfalfa-grass crop be harvested according to the maturity of the grass. Small grains, other than cereal silage crops grown as an alternative to corn as discussed above, should be harvested similar to grasses; i.e., prior to heading.

Harvest management of summer annuals can be influenced both by species and intended use (pasture vs. silage). First harvest BMR sorghum-sudangrass hybrids should be harvested for silage at 36-48" stand height, slightly less than this for second and succeeding harvests and under dry conditions. The crop will grow much taller than 48", but forage quality will quickly decline.

Mowing and chop height

Not surprisingly, mowing and chop height decisions involve a trade-off between yield and quality. Increased chop height of corn appears to have a more pronounced affect on quality than does the mowing height of alfalfa and grass. There is little advantage to increasing the mowing height of grass past the normal 2" or so, since grass quality doesn't change much from top to bottom of the plant. With any hay crop forage, mowing needs to be high enough to avoid scalping the field, which can contaminate the silage with soil, manure residues and crop debris. Increasing the chop height of corn from the normal 6-8" to 12-18" decreases yield but increases energy concentration, with lesser effects on fiber digestibility. Increasing chop height from 6" to 18" increases whole plant dry matter concentration by about 2 percentage points, which can be either a plus or a minus depending on crop maturity. If the crop is already higher in DM percentage than desirable, chopping high will only make the situation worse. Immature corn as well as BMR and other high NDF digestibility corn hybrids shouldn't be chopped higher than about 8". Corn silage crops that experience drought conditions can contain high levels of nitrates, which can have detrimental effects on feeding. Nitrates accumulate in the bottom portion of the plant so raising the cutter bar to leave about 12-18" (or more) of stalk in the field can be effective in reducing nitrate levels in the resulting silage.

Chop length and processing

The correct chop length for corn depends on whether or not the crop is processed. Processing silage crops does not give an economic benefit if the DM of the crop is <30%, but does so increasingly above this level. Processed corn should be chopped at 3/4" theoretical length of cut (TLC). Research has not shown any advantage to chopping shorter than this, while some custom processors report that chopping at 1" or longer has resulted in increased wear and tear on their equipment. Corn that is not processed should be chopped at a TLC of 1/4" to 1/2". The particle size of processed 3/4" TLC silage will be about the same as unprocessed 3/8" TLC silage. For processed silage, the roll clearance should usually be set at 1 to 3 millimeters, the specific clearance depending on both the equipment and the maturity of the crop. Processor maintenance is critical since worn rolls can result in a poorly processed crop with many unbroken kernels. If the corn is properly processed all the kernels should be broken, nicked or damaged, and there should not be any cob fragments larger than 1/4. A reasonable rule of thumb is that 40% of the kernels should be broken in half or smaller.

For most other forage crops, chop length can vary from 1/4" to 3/8" depending on how much of the ration consists of silage. To maintain good rumen function with all-silage rations, 3/8" TLC is preferred to shorter chop lengths.

Measuring forage particle size using the NASCO Penn State Particle Separator (Figures 5 and 6)continues to be a popular way to objectively evaluate if forages and TMRs have optimal particle size on the farm. The weight retained on each screen is compared with guidelines levels (Table 3). Recent field observations indicate if the top screen retention from screening a TMR is over 15 percent, cows may sort the ration. Feed particles in the middle box may be more important than the top box only.

If the four box system is used, the third screen

(1100 micron screen) should have about 2/3 of the material contained in the bottom box in the three screen system (for example, a TMR in the three box system is < 50% in the bottom box or < 35% in the third screen and < 15% on the box using the four box unit) (Table 4).

Figure 5: Particle Size Distribution Obtained from Chopping Silage Using NASCO Penn State Forage Particle Separator

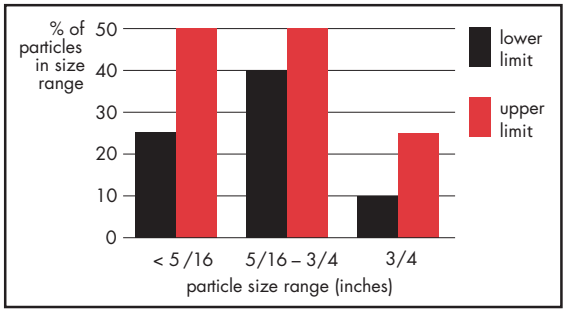

Figure 6: The NASCO Penn State Forage Particle Separator - 4 screen model

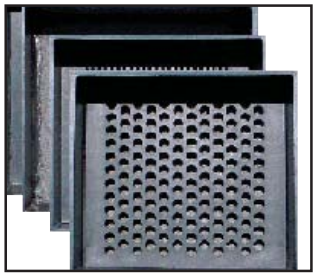

Table 3: Penn State Particle Size Box Guidelines expressed as a percent on an as-fed basis (three box separator)

	% OF TOTAL		
FEED TESTED	TOP	MIDDLE	BOTTOM
TMR	8-15	35-45	<50
Haylage	>20	>40	<25
Corn Silage (3/4" TLC, processed)	10-20	40-60	<35
Corn Silage (3/8" TLC, unprocessed)	<5	>50	<50

Table 4: Penn State Particle Size Box Guidelines expressed as a percent on an as-fed basis (four box separator)

	% OF TOTAL			
FEED TESTED	TOP	SECOND	THIRD	BOTTOM
TMR	10-15	>40	<35	<20
Haylage	>20	>40	<20	<5
Corn Silage (3/4" TLC, processed)	5-15	>50	<30	<5