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Minimizing HAY LOSSES — and — WASTE

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Hay harvest involves losses in dry matter and quality. These losses occur during all phases of getting the hay from the field to the livestock – harvest, storage, and feeding.

Hay is harvested, stored, and fed under a wide variety of conditions that influence both its yield and feed value. **High quality hay is useful in diets for livestock with high nutrient requirements** such as dairy cattle, growing and finishing beef cattle, lambs, and working horses. Excellent hay management is required to produce the hay needed by these livestock. High quality hay can be used as a supplement for lower quality forages, such as straw. Lower quality hay should be used for livestock that have lower nutrient requirements, such as gestating beef cows. Hay that is of very low quality will not only need supplementation when fed but will be subject to more refusal when feeding.

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Match Hay Type and Harvest Date to Nutrient Requirements of Livestock

Considerable costs are associated with producing and harvesting hay. The economic cost associated with dry matter losses during harvest, through storage, and with feeding waste is proportional to the production cost or market value of the hay. For example, a 25 percent hay loss on hay valued at $30 per ton effectively adds $10 per ton to the cost of the hay actually consumed. For hay valued at $60 per ton, the added cost is $20 per ton. Economic cost associated with loss of hay quality and nutrient availability can be even more substantial. Quality loss due to leaf shatter, weathering, spoilage, and heating may be associated with over $30 per ton lost value in high quality hay markets or a loss of production and performance when fed to livestock with high nutrient requirements.

Minimizing quality losses in the haying process and during storage is important; however, stage of maturity and type of hay are still primary determinants of hay quality. Table 1 gives the feeding value of different types of hay cut at different stages of maturity with good harvest management. As plants grow and mature, the concentration of fiber increases while protein content and digestibility decrease. Hay fed to animals with high nutrient requirements, such as high-producing dairy cows and performance horses, should be harvested at early growth stages, which are associated with high quality but typically lower yields.

Delaying hay harvest until more advanced stages of growth tends to maximize yields but at considerably lower quality. This is often appropriate when the hay will be fed to animals with lower nutrient requirements, such as gestating beef cows. Grass hays cut at early heading will often meet the cow's nutrient requirements, but delaying harvest until after pollen shed and seed filling may likely result in hay too low in protein to maintain cows without supplementation. Table 2 gives suggested stages for cutting hays to obtain high quality hay or maximum hay yield.

Reducing Harvest Losses

Cutting

Hay is usually cut with a sickle or drum type mower, a windrower, or swather. Cut after the dew is gone and when the topsoil is dry to reduce soil compaction and to hasten hay drying. A long stubble keeps the windrow off the soil surface to aid drying and improve subsequent pickup performance. However, high stubble height reduces forage yield. The acceptable windrow width for round balers is between one-half and near full width of the baler pickup.

Table 1. Feed value of selected hays.

Species	Stage of Maturity	Crude Protein	TDN	NE_m, Mcal/lb	NE_g, Mcal/lb	Relative Feed Value
		(%)	(%)			
Alfalfa	Bud	21.5	63	.62	.33	>150
	Early Bloom	18.4	59	.61	.28	125 - 149
	Mid-Bloom	15.9	55	.55	.25	103 - 124
	Full-Bloom	13.5	51	.53	.21	75 - 102
Brome	Early Boot	15.0	63	.62	.33	>125
	Early Heading	10.5	58	.60	.26	100 - 124
	Early Milk	8.0	54	.58	.19	76 - 99
	Mature	6.0	48	.56	.15	<75
Prairie Hay	Early Boot	10.8	63	.63	.34	>125
	Early Heading	8.7	55	.56	.26	95 - 124
	Early Milk	6.2	50	.49	.21	80 - 94
	Mature	4.8	46	.47	.15	<80

Information condensed from NEB GUIDES G84-738-A and G88-874-A; University of Nebraska.

Authored by Bruce Anderson, Extension Forage Specialist; Terry Mader, Extension Beef Specialist; John A. Smith, Extension Machinery Systems Engineer; Robert D. Grisso, Extension Agricultural Engineer; Kenneth Von Bargen, Professor, Agricultural Engineering Department; Bruce Anderson, Extension Forage Specialist.

Table 2. Recommended stages of maturity for harvesting high quality hay or for maximum yields.

Crop	Stage for High Quality Hay	Stage for Maximum Hay Yield
Alfalfa	First cutting – late bud Other cuttings – early bloom	Mid-bloom
Brome or Crested	Boot stage	Flowering
Cereal Grains	Boot stage	Soft dough
Prairie Grass	Boot stage	Late head

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Conditioning – Conditioning of legumes speeds drying by opening the waxy layer surrounding the stem. Large or coarse stemmed hays tend to respond to conditioning better than fine stemmed hays.

Raking – When possible, eliminate raking by using a windrower. Windrowed hay will dry slower than hay in a wide swath. More leaf loss can be caused by raking dry alfalfa than by any other harvest operation. Avoid raking when the forage moisture is less than 40 percent.

Hay Desiccants – Hay desiccants are used to reduce the length of time needed for hay drying. The chemical drying agent is sprayed onto the hay during cutting to remove the moisture-conserving, waxy cutin layer of alfalfa, clover and birdsfoot trefoils. This allows the stem to dry faster and can reduce the interval between cutting and baling. Hay desiccants may decrease time needed for drying by one third. However, hay desiccants are ineffective on grasses such as orchardgrass, timothy, or bromegrass. Hay desiccants work the best in good drying conditions and are less effective in poor drying conditions. Leaching losses may be greater in desiccant-treated alfalfa if rained on before baling.

Hay desiccants commonly used are potassium carbonate or sodium carbonate. Potassium carbonate is applied at 5 to 7 pounds of active ingredient per acre through a mixture sprayed at 15 to 30 gallons per acre. Equipment cost for applications can be high (approximately $1,200 for a sprayer to be mounted on a 9 foot mower) with moderate expense for product ($5 to $6 per acre).

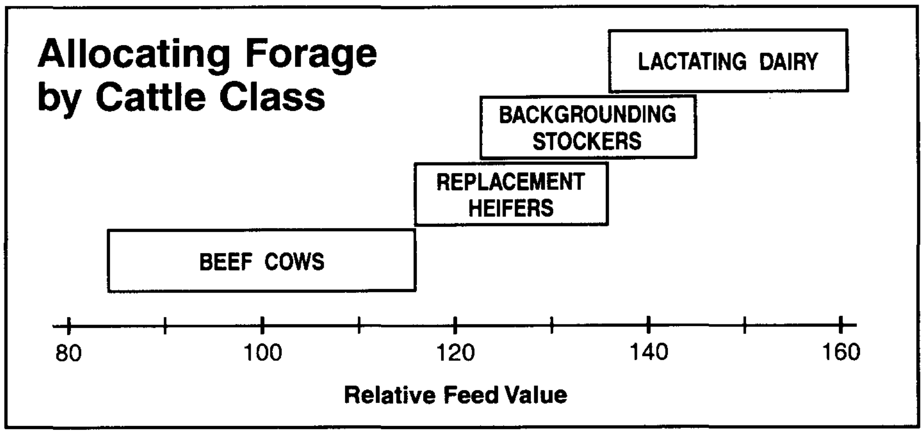

Figure 1. Allocation of hays to various classes of livestock based on relative feed value (RFV).

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Respiration Losses

After cutting, plant cells respire until moisture content falls below 35 to 40 percent. Hay that dries quickly will lose 2 to 6 percent dry matter (DM) due to respiration. Hay that dries very slowly may lose 15 percent DM due to respiration. Cutting hay when good drying weather is expected will reduce respiration losses considerably.

Weathering Losses – Rain (leaching) can cause up to 20 percent nutrient loss. Carbohydrates, B vitamins, and some soluble minerals are readily leached from dry hay.

Time of Cutting – Natural physiological processes in plants cause the concentrations of soluble carbohydrates and other highly digestible nutrients to peak in the evening. Recent research suggests that hay cut at or near sundown is higher in energy than hay harvested at sunup.

Baling Losses

Field losses of 1 to 5 percent have been measured for small rectangular balers operating in typical conditions for alfalfa hay. Under these same conditions, field losses of 3 to 30 percent have been measured for large round balers.

Hay Moisture Content – Hay moisture content is the largest single factor contributing to leaf loss. Hay baled at a moisture content above 15 percent has much less leaf loss than hay baled below 15 percent moisture. The upper moisture limit to prevent mold growth and other hay deterioration for large round alfalfa bales is typically 18 to 20 percent. Hay baled above 25 percent moisture will usually spoil unless chemical preservatives are added to the hay. Hay that is put up too wet also increases the chance of fire, especially when stored indoors.

When the hay becomes too dry and brittle and losses become excessive, stop baling and resume in the evening or morning when the leaf moisture level increases.

This dew-moistened hay can be baled at a slightly higher moisture level than when it was drying down because dew moisture in the hay is more easily released during curing than internal moisture. In addition, moisture gauges tend to read higher than the actual moisture content in dew-moistened hay.

A number of commercial moisture testers are available for use in determining hay moisture levels. Some operate using a sample of hay, while others operate using a probe. Generally, the probe models are simpler to use since they do not require taking a sample. A number of readings should be taken and averaged to get the most accurate moisture determination. Probe several bales at different locations in the field to account for field variations. Square bales should be probed from their ends while round bales should be probed through their diameter.

Hay preservatives – Hay preservatives allow harvesting of hay at higher moisture content. Advantages of hay preservatives include: 1) allowing hay to be baled at higher moisture levels, which may reduce the risk of rain damage, 2) baling at higher moisture levels reduces dry matter and nutrient losses caused by leaf shatter, and 3) lengthening the potential baling period by allowing hay to be baled at higher moisture levels. Disadvantages of hay preservatives include: 1) some preservatives, such as propionic acid, are corrosive and can damage machinery and injure workers, 2) some preservatives have not been tested thoroughly under a wide variety of haying conditions, and 3) some preservatives may not be cost effective.

Hay preservatives have been classed into several types: organic acids, acid salts, salt (NaCl), anhydrous ammonia, urea, fermentation products, anaerobic bacterial inoculants and aerobic bacterial inoculants. The organic acids (propionic, acetic, citric) are very effective in preventing mold and heating. As hay moisture content increases, the amount of acid needed increases (Table 3).

To reduce corrosiveness, propionic acid can be buffered with ammonium hydroxide. Some manufacturers mix buffered propionic acid with citric acid (used to retain green color) and use lower application rates to reduce mold and heating. However, most research data suggests that the amount of acid applied should approach levels given in Table 3 to be effective. Product cost is suggested at $4 per ton of hay baled at 18 to 22% moisture, $8 for 22 to 26 percent moisture hay, and $16 for 26 to 30 percent moisture hay.

Microbial products developed to aid ensiling (anaerobic products) appear to have limited effectiveness when used for hay preservation. According to research conducted in Michigan, anaerobic products did not appear to be effective at preserving 25 percent moisture hay. Aerobic products appear to give variable results. Microbial products appear to work best with liquid application and may be priced less than the organic acids. Follow manufacturers' recommendations for application and storage of microbial solutions to retain bacterial viability.

Alfalfa and other hays store best when moisture is below 20 percent. However, rain and soil moisture can delay hay drying and subsequent baling. Hay preservatives can be used to maintain quality in hay baled at higher moisture levels (up to 30% or higher). However, preservatives have a cost in both application machinery (up to $3,000 for automated equipment) and preservative product (up to $16 per ton for 30 percent moisture hay).

Table 3. Application rates when using propionic acid as a hay preservative.

	Propionic acid to be added	
Hay Moisture	**% of Dry Weight**	**Pounds per ton of Hay**
20 to 25%	0.5	10
25 to 30%	1.0	20
30 to 35%	1.5	30

Table adapted from the following bulletins:
J.F. Shanahan, and D.H. Smith, 1998, #0.705 Colorado State University;
J.C. Henning and H.N. Wheaton, 1993, G04575, University of Missouri-Columbia;
B. Weiss and J. Underwood, 1992, AGF-013092, The Ohio State University.

Baler Pickup – The pickup mechanism of large round balers may cause losses as high as 12 percent, although losses more typically range from one to three percent. Field speed, size of windrow, hay moisture content, and mechanical condition of the pickup influence this loss. Higher moisture content reduces pickup loss. Lowering field speed in general, and synchronizing field speed to pickup rotational speed in particular, reduces pickup loss. Heavy windrows reduce pickup loss by reducing field speed and contact with pickup components.

Bale Chamber – Bale chamber losses have been measured as high as 18 percent for large round balers. Bale chamber losses are normally two or three times higher in a large round baler than a rectangular baler. Windrow size, field speed, hay moisture content, bale rotating speed, and wrapping of twine or netting contribute to chamber losses.

To minimize bale chamber losses, the moisture content should be as high as possible to permit safe storage and the feed rate should be as high as possible to minimize the number of turns within the bale chamber. A high feed rate can be attained by using large windrows and high field speeds. Where windrows are small or field speeds must be low, use a lower PTO speed. This results in fewer revolutions to form a bale.

When wrapping twine, do not rotate the bale more times than necessary to secure the twine. The leaves which fall from the bale chamber during twine wrapping are an indication of the bale chamber loss.

Reducing Storage Losses

Large round bales typically have a higher storage loss than rectangular bales, especially when stored outdoors. There are a number of storage techniques that minimize outdoor storage loss.

- **Make a dense bale** – A dense bale will sag less and have less surface area in contact with the ground. A dense surface layer will shed more precipitation and protect the inner part of the bale from weathering. Bale density should be at least 10 pounds per cubic foot to facilitate resistance to weathering. As bale density increases, the rate at which moisture and heat escape decreases. Therefore, it is critical that dense bales be baled at the proper moisture (18 to 20 percent or less) so that risk of spoilage and heating problems are reduced.
- **Thatch formation** – In theory, a round bale should form a thatch layer which will help shed water and precipitation. Certain hay crops tend to form thatch better than others. For example, fine stemmed grass hays which are free of weeds tend to thatch well. However, coarse or hollow-stemmed hays, such as sudan grass and other warm season annuals, do not form thatch well.
- **Store bales on a well-drained location** – Bales soak up moisture if placed on a wet or poorly-drained site, causing a large layer of spoiled hay on the bottom of the bale. The storage site should drain away in all directions. A well-drained, 4- to 6-inch coarse rock base will minimize bottom spoilage. Rock base may need to be deeper depending on the weight of equipment used to store and retrieve bales as well as the soil type.
- **Locate bale rows away from tree rows** to avoid accumulation of snow and contact with snow drifts and to allow wind to dry the hay after rain or snow.
- **Do not store bales under trees or other areas where drying is impaired.**
- **Store bales end to end** – The arrangement of large round bales in outdoor storage can significantly influence the amount of storage loss. Under most conditions, position bales end to end in long lines. If more than one line of bales is needed, space adjacent lines at least 10 feet apart. This will minimize snow buildup between rows and allow the sun to reach the back row. Stacking large round bales usually increases losses. Stacking tends to trap moisture and limit drying action from exposure to the sun and wind.
- **Store bales in rows which run up and down the slope with a north/south orientation** – A southern exposure is best to promote rapid drying following precipitation.
- **Indoor storage and bale covers** – If bales are to be marketed or stored for more than one season, indoor storage or bale covers should be considered. Remember that the outer 4 inch thick layer of a 6 foot diameter round bale contains about 25 percent of the total bale volume (See Figure 2). Studies have shown outdoor storage losses range between 5 and 35 percent depending on the amount of precipitation, storage site location, and original condition of the bale. Storage losses are usually reduced by approximately two-thirds with indoor storage and by one-half with good plastic covering outdoors.
- **Bale size** – Everything else being equal, smaller diameter bales have greater amounts of bale volume exposed to the elements per unit of surface area. This results in increased weathering and spoilage as bale size decreases (See Figure 2).
- **Amount of precipitation expected** – Consider that a 6-foot wide, 6-foot diameter bale will receive 22 gallons of water for every inch of rain. If 10 inches of rain are received during the storage period, the bale will receive 220 gallons of water.

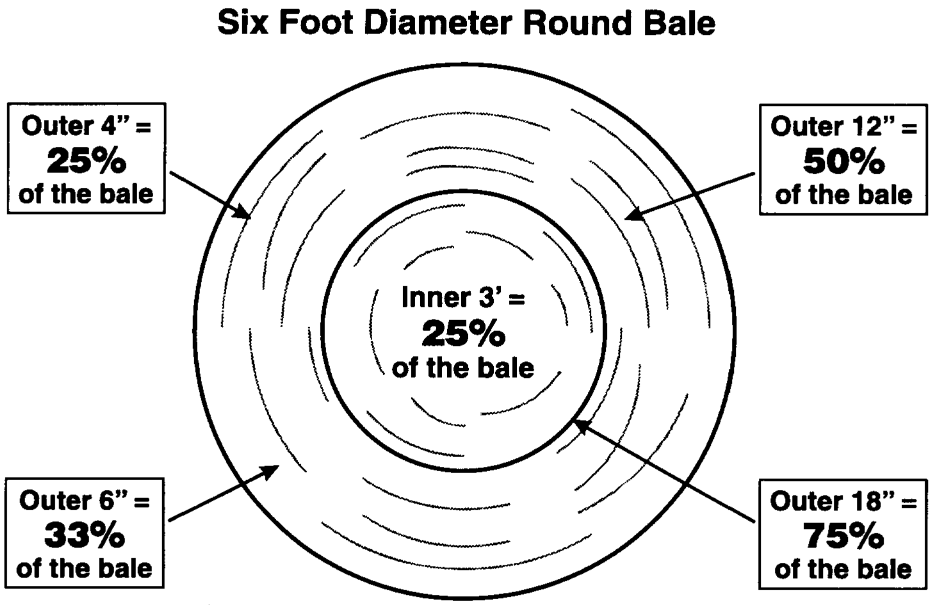


Figure 2. Effect of depth of spoilage on hay waste (%).

Reducing Feeding Losses

Much expense and many hours go into harvesting good quality hay and storing it for winter feeding. You wouldn't dream of throwing away one-third of this hay. That is what happens, though, when livestock are allowed unlimited access to hay. When hay is fed with no restrictions, livestock trample, over-consume, foul, and use hay for bedding, wasting 25 to 45 percent of the hay (Table 4).

Cattle will waste less hay when the amount fed is limited (Table 5). One-fourth more hay is needed when hay is fed free access than when a one-day supply is fed.

Excessive hay consumption can be a major problem when large amounts of hay are fed without restriction. A dry pregnant cow will eat 20 to 30 percent more hay than her needs when allowed free access to hay. This can amount to over 700 pounds per cow over a four-month feeding period for spring calving cows. This is in addition to the hay wasted when fed free access. Compared to feeding a several-day supply each time hay is provided, daily feeding will force livestock to eat hay they might otherwise refuse, over-consume, trample, and waste. If multiple-day feeding is used, match the quality of the hay to the nutrient requirements of the livestock to avoid over-consumption.

Grinding or chopping hay reduces waste and sorting. Ground hay reduces losses due to sorting, trampling, and refusal of long stemmed hay. Grinding also allows the use of mixed rations to increase the palatability of coarse or "stemmy" hays. Ground hay can be fed in turned tires or bunks to reduce losses and waste due to wind.

Table 4. Hay wasted by cows when fed with and without racks.

Bale Type	Percent Wasted
Square bale in rack	7
Large round bale in rack	9
Large round bale without rack	45

Source: Bell, S., and F.A. Martz. 1973. Res. Rep. Univ. of Missouri Agric. Exp. Sta. Columbia, MO.

Table 5. Hay wasted by cows when amount fed was controlled.

Feeding System	Hay per Cow Per Feeding	Hay Refused or Wasted	Hay Required Over Rack Feeding
	(lbs)	(percent)	(percent)
Rack feeding on pasture	—	5	—
No rack feeding on pasture			
1-day supply per feeding	20	11	12
2-day supply per feeding	40	25	33
4-day supply per feeding	80	31	45

Source: Smith, W.H. et al. 1974. ID-97. Purdue Univ. Coop. Ext. Serv. W. Lafayette, IN.

Table 6. Effect of feeder type on waste and apparent intake of round-baled hay fed to cows.

	Round Bale Feeder Type			
	Ring	Cone	Cradle	Trailer
Hay dry matter disappearance, lbs/cow/day	26.8	26.4	28.4	30.6
Hay dry matter waste, lbs/cow/day	1.6^{a}	$.9^{a}$	4.2^{b}	3.5^{b}
Waste, % dry matter basis	6.1^{a}	3.5^{a}	14.6^{c}	11.4^{b}
Estimated dry matter intake, lbs/cow/day	25.1	25.4	24.3	27.1
Estimated dry matter intake, % cow BW	1.84	1.76	1.82	1.96

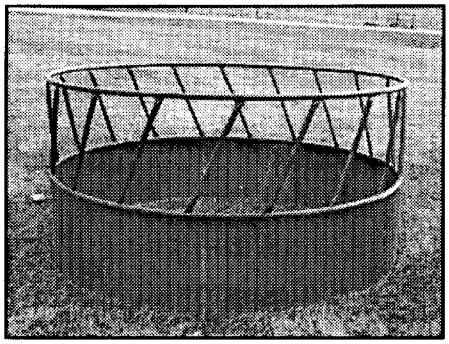
^{abc}Within a row, means lacking a common superscript letter differ ($P < .05$).

Data adapted from Buskirk et al., 1999. Michigan State University.

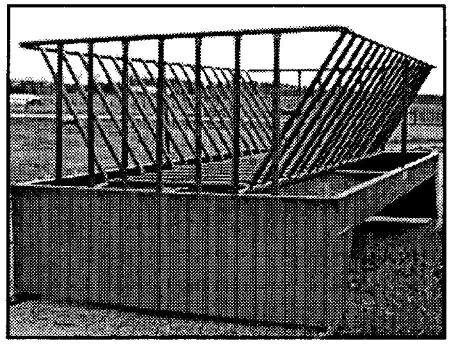
Use restricted access whenever possible. Feed bunks are excellent for feeding small square bales. Round bales should be fed in specially designed racks. Loose or compressed hay stacks should have collapsible racks or electric wire around them to reduce trampling the hay around the edges. Hay racks with solid barriers at the bottom prevent livestock from pulling hay loose with their feet and dragging it out to be stepped on. Feeder type influences the amount of hay wasted by cattle. Recent research completed at Michigan State University compared feeding round bales in ring, cone, cradle, and trailer type feeders. Cone and ring feeders had the least waste while cradle and trailer type feeders had the most (Table 6). The types of feeders used in this study are pictured in Figure 3.

If hay must be fed on the ground, take steps to minimize the amount of hay wasted by trampling. Feeding hay in limited quantities, feeding on frozen ground, and feeding palatable hay will minimize the sorting and trampling that can occur in these feeding systems. No matter how hay is fed, efforts that limit the amount of hay accessible to trampling will save feed. Feed hay at a well-drained site or on concrete when possible.

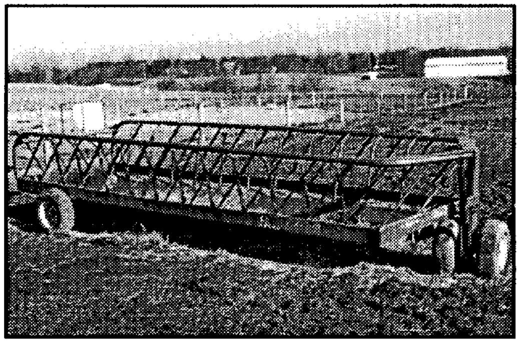
Table 7 lists the dry matter losses that occur when handling hay from field to feeding. By the time the hay is fed, losses can be substantial and can essentially increase the amount of production needed from the original standing crop by 35 percent. Effectively controlling the amount of hay lost and wasted during harvest, storage, and feeding can reduce production costs and make hay more profitable.



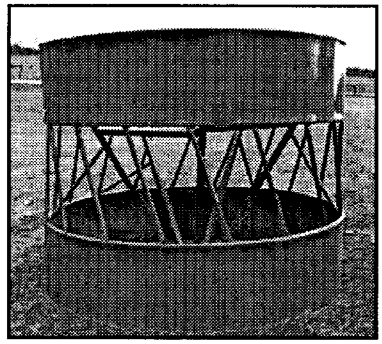
Ring



Cradle



Trailer



Cone

Figure 3. Round bale feeder designs used in the Michigan State University study (Buskirk et al., 1999).

Photos courtesy of Michigan State University.

Table 7. Percent dry matter losses of hay from field to feeding.

	Range	Average
Mowing	1 to 6	3
Raking	5 to 20	10
Swathing with conditioner	1 to 10	5
Plant respiration	2 to 16	5
Baling, % of windrow	1 to 15	5
Storing, % of stack		
Outside	5 to 30	15
Inside	2 to 12	5
Transporting hay	1 to 5	3
Feeding, % of stack or bale		
With feeder	1 to 10	5
Without feeder	2 to 45	15
Total, percent of original standing crop	10 to 80	35

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Summary

Hay harvest and feeding involves losses in dry matter and quality. These losses occur during all phases of getting the hay from the field to the livestock – harvest, storage, and feeding. Matching the quality of the hay to the nutrient requirements of your livestock can be an effective way to better utilize existing hay supplies.

Harvest losses can be reduced by a number of methods, including using hay desiccants and properly adjusting equipment to field conditions. Baling losses can be a significant problem under some production conditions. Baling hay at the proper moisture, hay preservatives, and proper baler adjustment are ways to reduce hay losses which occur during baling.

Storage losses can be significant, depending on the amount and type of precipitation, type of bale, and storage method. In some cases, it may be necessary to use indoor storage to preserve nutrients in high quality hays.

Feeding losses also represent an area where hay losses can be high. The method of feeding, type of bale, type of hay, and type of bale feeder all play a role in determining the amount of waste in a given feeding operation.

Under poor management, hay losses and waste reduce efficiency and erode profits. Paying attention to details at harvest, baling, storage, and feeding losses can reduce waste and increase profitability of your haying or feeding enterprise.

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