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Chapter 7

CONSERVING HAYS - FROM PRODUCTION TO CONSUMPTION

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Chapter 7

CONSERVING HAYS - FROM PRODUCTION TO CONSUMPTION

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Plants have been harvested and conserved for feeding since the beginning of recorded history. Conserved forages serve one basic purpose - providing flexibility to a forage-livestock enterprise. Conserved forages add flexibility to the forage-ruminant system by: (1) serving as a feed source during periods of stress (drouth, winter, etc.), (2) allowing greater grazing intensities on a year-round basis, (3) providing a means of maintaining forage quality during periods of abundant plant growth, (4) offering a more efficient means of utilization of forage produced. The tremendous values and untapped potentials of conserved forages as a part of the plant-animal production scheme are illustrated by the statement, "grazing attempts to equate current forage availability to the current needs of the animal; whereas, conservation provides a buffer between crop production and animal feeding" (Raymond, 1969).

Hay is one of the oldest types of conserved forages. Even though hay meets all the above flexibility factors, considerable inefficiencies are associated with the process of hay-making. Perhaps the most inefficient and expensive part of conserving forage as hay results from losses of dry matter and nutrients during harvesting, drying, storing, and feeding. Certain losses are inevitable in forage conservation, but many of these losses may be minimized and nearly eliminated by following proper techniques of forage conservation.

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HARVESTING AND DRYING - MECHANICAL

Preservation of forage quality is an important consideration in the development of mechanized forage harvesting and handling systems. A major obstacle to a high quality product is the initial moisture content of most forage crops at the optimum stage of maturity. The moisture content of forages at this optimum stage is usually 75 percent and above.

The high energy requirements to remove large amounts of moisture from fresh-cut forage make it difficult to find economical artificial drying methods. In high-moisture forages, 7,000 pounds of water must be removed from 80-percent-moisture forage to produce one ton of hay at 10 percent moisture. The energy required to dry forage can be reduced considerably by allowing it to partially dry in the field before the artificial drying operation. If the moisture content of forage is reduced to 50 percent in the field, only 1,600 pounds of water must be removed to produce 1 ton of 10-percent-moisture hay. However, the drying rate of the cut forage should be as fast as possible in the field to reduce exposure time to a minimum and lessen chances for quality reduction. A fast drying rate is even more important for forage that is completely dried in the field.

Physical Properties of Forage Plants Related to Drying

Since the preservation of quality is closely related to the time required for drying, initial moisture content and drying rate are important factors in selecting a forage crop and/or improving quality within varieties. In developing a variety with reduced field drying time, either or both factors may be considered; in selecting forage crops to be planted for feeding purposes, both factors must be considered.

From the standpoint of energy requirements for removing moisture from forages, it is desirable to have as low an initial moisture content as possible when the forage is at the stage of maturity for the highest quality. Examples of forage crops that have this low initial moisture content characteristic are kleingrass and Coastal bermudagrass (Table 7-1).

Table 7-1. Initial moisture content and time required to reduce moisture content of several forage crops to 50 and 20% (w.b.).

Forage crop	Initial moisture content, %	Hours required to reduce moisture content to: 50%	20%
Alfalfa	77.5	4.6	19.4
Coastal bermudagrass	68.1	3.4	20.4
Kleingrass	66.1	3.1	16.0
Perennial sweet sorgrass	86.8	55.5	--

Sorenson and Person, 1967.

The time required for several forage crops to dry under somewhat ideal but equal drying conditions in laboratory tests is also shown in Table 7-1. Test results showed that alfalfa actually had the fastest drying rate of the forage crops studied, but kleingrass reached the 20 percent level first because of its lower initial moisture content. Kleingrass had a slightly higher drying rate than Coastal bermudagrass and normally reaches a storable moisture content before Coastal bermudagrass, depending upon the initial moisture contents. Perennial sweet sorgrass had the highest initial moisture content and the lowest drying rate of the crops tested.

Field Drying Forage Crops

The basic pieces of equipment for harvesting and packaging field dried forages are the mower, rake, and baler to cut, consolidate, and compact material. In recent years, the addition of some type of mechanical hay conditioner has proven to be valuable in the preservation of quality. These conditioners may be power driven by the tractor or incorporated in a self-propelled unit. In either case, the conditioning unit normally will crush the material between steel and hard rubber rolls or will crimp the forage by passing it between corrugated steel rolls. The former is referred to as a hay crusher and the latter as a hay crimper.

Effect of Harvest Method on Field-Drying Time

Any method of harvesting forage crops that reduces field drying time is important because quality deterioration is directly related to field exposure time. The times required to field-dry alfalfa and sudangrass by several different methods are given in Table 7-2.

Table 7-2. Hours required to field-dry alfalfa and sudangrass to moisture content of 50 and 25% (wet basis)

Treatment[1]	Hours required to reduce moisture content to: 50% (wet basis) Alfalfa	Sudangrass	25% (wet basis) Alfalfa	Sudangrass
Mow - dry in swath	5.5	50.0	39.5	54+[2]
Mow - windrow immediately - dry in windrow	23.3		50.7	
Mow - dry in swath to 50% - windrow - dry in windrow			40.8	
Mow - crush - dry in swath	3.7	5.9	25.2	28.7
Mow - crush - windrow immediately - dry in windrow	6.6		37.9	
Mow - crush - dry to 25% - windrow - dry in windrow			35.8	
Mow - windrow immediately - crush - dry in windrow	5.7		25.7	
Mow - crimp - dry in swath		6.6		28.3
Cut with flail harvester - dry in swath		24.4		31.0

[1]Alfalfa and sudangrass were harvested during May and June, respectively.

[2]Test was ended after sample was in field 54 hours. Moisture content after 54 hours was 45 percent.

Sorenson and Person, 1967.

Alfalfa that was mowed and dried in the swath required 39.5 hours to reach a 25 percent moisture level. When a crusher was used with this method, approximately 14 hours were saved. The moisture content of alfalfa that was mowed, crushed, and then dried in the swath was reduced to 25 percent in 25.2 hours compared to 25.7 hours when alfalfa was mowed, immediately windrowed, crushed, and then dried in the windrow. The latter method shows considerable promise because quality loss from leaf shattering and sun bleaching is less.

When sudangrass was mowed and allowed to remain in the swath, 54 hours were required to reduce the moisture content to 45 percent (Table 7-2). The time necessary to dry to 25 percent moisture content was estimated to be about 192 hours. When a hay crusher and crimper were used, the field-drying time required to reduce the moisture content to 25 percent was 28.7 and 28.3 hours, respectively.

A flail-type harvester reduced the field-drying time on sudangrass to 31 hours to reach a moisture content of 25 percent. This drying rate compared favorably with the crushing and crimping methods. However, excessive dry matter losses occurred when this machine was used (Table 7-3).

Table 7-3. Field harvesting efficiency tests.

Treatment	Percent moisture at time hay picked up, wet basis: Alfalfa	Sudan	Yield/acre lbs dry weight: Alfalfa	Sudan	Percent loss compared with check: Alfalfa	Sudan
Mow - pick up immediately by hand (check treatment)	70.1	77.1	1,398.3	2,935.9		
Mow - dry in swath - rake - pick up with forage harvester	21.3	50.5	1,158.7	2,365.3	17.1	19.4
Mow - crush - dry in swath - rake - pick up with forage harvester	15.5	26.1	1,097.7	2,400.2	21.5	18.2
Mow - crimp - dry in swath - rake - pick up with forage harvester	18.0	25.1	1,267.6	2,330.5	9.3	20.6
Cut with flail harvester - dry in swath - rake - pick up with forage harvester	16.8	27.4	283.1	1,254.5	79.8	57.3

Sorenson and Person, 1967.

Harvesting loss for sudangrass with a flail harvester was 57.3 percent compared to an average of 19.4 percent for the other methods. Harvesting losses for alfalfa were 79.8 percent with the flail harvester compared to an average of 16.0 percent for the other methods.

When artificial drying is used in conjunction with field drying, the time the forage is in the field after cutting is greatly reduced. Under these conditions, the value of using a hay conditioner for alfalfa is questionable. However, the conditioner may be justified if the moisture content is to be reduced to 20 percent with artificial drying because the time required for drying is shorter. In comparative drying tests under controlled conditions, crushed alfalfa reached a moisture content safe for storage in a 59.6 percent shorter time period than unconditioned alfalfa (Figure 7-1). When the material was crushed, a 26.4 percent time-saving resulted.

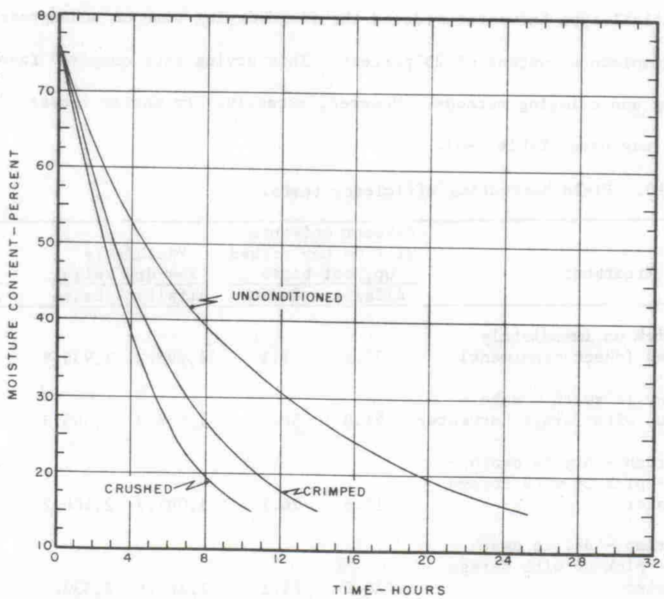

Figure 7-1. Comparison of moisture content at various hours during the drying period for different methods of conditioning alfalfa.

Sorenson and Person, 1967.

Effect of Different Treatments on Drying Rate

Flaming Alfalfa

Flaming alfalfa with a conventional flame cultivator made little difference in the time required to dry flamed and unflamed forage to a moisture content of 25 percent. However, a saving of 20 hours resulted in field-drying flamed, conditioned (crushed) alfalfa as compared to unflamed, unconditioned alfalfa.

Drying with Infrared Radiation

Most applications that use radiation as a mechanism of heat transfer have dealt with a particular range in the electromagnetic spectrum known as infrared.

When single layers of hay are exposed to infrared energy from different sources, the higher the radiation intensity and the longer the exposure period for each source, the greater the rate of moisture removal (Figure 7-2).

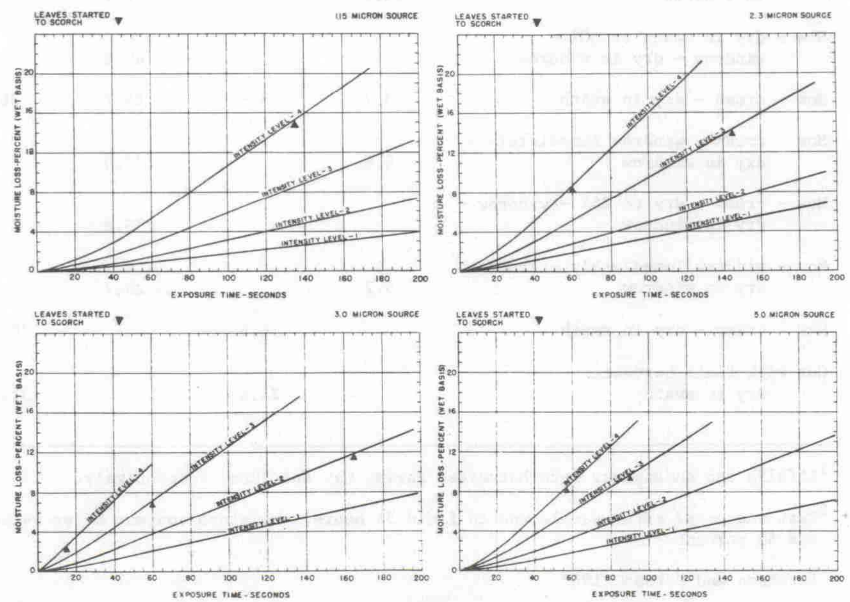

Figure 7-2. The rate at which moisture was removed from alfalfa hay irradiated for different exposure times under different sources of infrared radiation.

Sorenson and Person, 1967.

A major problem encountered in infrared drying is scorching of leaves. For each radiant energy source, the exposure time before scorching occurs is apparently related to the drying rate. The higher the intensity level, the faster the hay scorches; consequently, the maximum exposure time for the high intensity levels is extremely short, and moisture removal is inadequate. There also appears to be some relationship between time before scorching and initial moisture content.

Heat and Pressure Treatments

Studies have been made to determine the effects of heat and pressure treatments on altering the drying characteristics of alfalfa in an attempt to increase its drying rate.

Samples were subjected to temperatures ranging from 100 to 1,000°F under chamber pressures of minus (-) 75 cm Hg to 150 psig. Samples were held at the desired temperature and pressure for various lengths of time, after which the pressure, or vacuum, was suddenly released. Cell wall eruption or other cellular changes that might speed up drying rate were evaluated but no changes were observed. Neither was subsequent rate of drying altered by the treatments.

Freeze Treatments

Laboratory experiments have been conducted to determine the effect of freeze treatments on the drying rate of unconditioned, crushed, and chopped alfalfa hay. The tests included various treatment combinations using slow-freeze and quick-freeze processes. Liquid nitrogen was used to obtain a quick-freeze (less than 15 seconds); whereas, slow-freeze was obtained by suspending the sample in a deep-freeze unit for 24 hours. Following each treatment, the samples were placed in a conditioned room held at 85°F and 60 percent relative humidity.

The time required for the samples to reach 20 percent moisture, wet basis, (Figure 7-3) was decreased significantly by freezing when compared to unfrozen, but freezing rapidity made no further difference. Chopped hay, frozen or unfrozen, showed the fastest drying rate, followed by crushed and uncrushed hay, in that order.

A quick-freeze treatment applied to the standing crop or in the swath may be a fruitful approach to the problem of moisture release from drying forage, provided no serious effect on nutritive value is found.

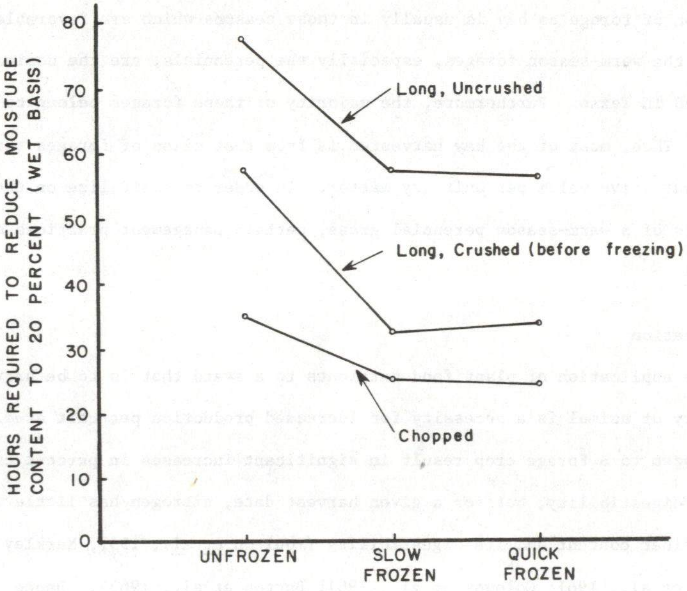

Figure 3. Effect of freeze treatments on the time required to reduce the moisture content of uncrushed, crushed and chopped alfalfa hay to 20 percent, wet basis.

Sorenson and Person, 1967.

HARVESTING AND DRYING - EFFECTS ON NUTRITIVE VALUE

Quantity vs Quality

A seemingly infinite number of conditions and situations govern the selection of a forage species that is to occupy a given land area. One attribute that the crop must possess is the potential of rapid production of high quality forage. Since the conservation of forage as hay is usually in those seasons which are favorable for field curing, the warm-season forages, especially the perennials, are the dominant species conserved in Texas. Furthermore, the majority of these forages belong to the grass family. Thus, most of the hay harvested is from that class of forages that has the lowest nutritive value per unit dry matter. In order to capitalize on the available nutrients of a warm-season perennial grass, certain management practices must be observed.

Fertilization

The application of plant food nutrients to a sward that is to be harvested via machinery or animal is a necessity for increased production per unit area. Additions of nitrogen to a forage crop result in significant increases in percent crude protein and its digestibility, but for a given harvest date, nitrogen has little if any effect on the fiber content and its digestibility (Poulton et al., 1957; Markley et al., 1959; Chalupa et al., 1961; Colovos et al., 1961; Burton et al., 1963). Hence, digestible energy of a perennial grass is only slightly altered by nitrogen fertilization (Blaser, 1964). And, since digestible energy from a perennial grass is one of the first limiting factors to animal performance, the application of fertilizers as a means of increasing forage nutritive value per se is of minor importance. The main benefit associated with increased fertility levels is that of increased forage quantity.

Harvesting

Forage harvested as hay must be cut at a frequency to provide adequate quantity and to minimize reductions in quality because of plant maturity. The yield of Coastal

bermudagrass increases with weekly delays in harvest frequency from 1 to 6 weeks (Prine & Burton, 1956). Yields are not increased by harvesting less often than every 6 weeks. Burton et al. (1963) and Holt and Lancaster (1968) also showed that Coastal bermudagrass yields increased with less frequent harvest with maximum dry matter production occurring at the 6-week frequency. Nutritive value, however, declined with each delay in harvest. It was further shown that a 4- to 5-week harvest frequency of Coastal bermudagrass produced the maximum quantity of high quality hay.

Field Curing

Any forage conserved as hay must undergo a period of drying or curing prior to storage. During this phase of forage conservation, the greatest nutrient and dry matter losses may occur. Carter (1960) reported that barn drying is greatly superior to field drying as a method of curing hay. Dry matter and nutrient losses from field-cured hay are often twice that of barn-cured hay. Weather conditions during the drying period are primarily responsible for differences in losses that occur between the two methods.

Dry Matter and Nutrient Losses

Dry matter and nutrient losses during field drying may be attributed to: (1) Plant respiration. Total losses may range from 1 to 11 percent (Melvin and Simpson, 1963), occur as rapidly as 3.5 percent in 24 hours (Hesse and Kennedy, 1956), and terminate when moisture content reaches 35 percent (Greenhill, 1959); (2) Leaf shattering. Dry matter losses, primarily with legumes, of 20 percent (Shepherd et al., 1954) and crude protein losses of 9 to 11 percent (Shepperson, 1960) have been reported; (3) Leaching via rainfall. Dry matter losses range from 3 to 11 percent with bermudagrasses (Hart and Burton, 1967) and from 40 to 50 percent with alfalfa (Shepherd et al., 1954). Nutrient losses may be as high as 50 percent (Murdock & Bare, 1963).

Carotene Losses

Once the forage has been cut, carotene is one of the most easily destroyed nutrients (Carter, 1960). The loss of carotene is a function of total solar radiation during curing (Hart and Burton, 1967). Hart and Burton (1967) also reported a 67 percent loss of carotene on bright days, and with 2 such days in succession a 90 percent loss could occur. Carter (1960) indicated carotene losses of 90 to 95 percent for field-cured hay, 80 to 90 percent for barn-dried hay, and 40 to 60 percent for silage.

Pelleting

Pelleting is one method of forage conservation that eliminates the field curing phase of hay making. Forage conserved as pellets is harvested mechanically via silage or soiling equipment, hauled directly to a pelleting mill, and then artifically dried, ground, and pelleted. Thus, high dry matter and nutrient losses associated with field-drying are essentially eliminated.

Review articles by Reynolds and Lindahl (1960), Minson (1963), Beardsley (1964), and Moore (1964) on the effect of pelleting on feeding value showed conclusively that: (a) The voluntary intake of pelleted forages is higher than that of the same forage which is in a long or coarsely chopped form. Furthermore, the difference between intake of the two forms of forage increases with poor quality roughage and decreases with high quality roughage. The increased intake of pelleted roughage may be because forage palatability is increased after the forage has been finely ground (Meyer et al., 1959 and Tillman, 1961). (b) The dry matter digestibility of long forage is greater than that of pelleted forage. Blaxter et al. (1956) concluded that the decreased dry matter digestibility of the finely ground, pelleted forage was related to its higher rate of passage through the reticulo-rumen. (c) An improved feed-conversion efficiency and increased liveweight gain are associated with the increased feed intake. Because pelleting increased intake, a smaller proportion of the diet is needed for maintenance, which in turn explains the improved feed-conversion efficiency (Minson, 1963). Furthermore, most of the large responses of liveweight gain due to pelleting have occurred on poor quality rations, with only small gain responses occurring on high quality rations.

It is most important to remember that these effects vary among forage species and with stage of maturity (Heaney et al., 1963). The benefits associated with pelleting are primarily a result of grinding the forage, and these benefits are magnified in lower quality roughages. Reductions in dry matter and nutrient losses during the harvesting-

drying phase of forage conservation and increased animal performance make pelleted hay one of the most efficient methods of forage conservation and utilization that is available. However, costs involved in the pelleting of forages have not allowed widespread use of this technique.

STORAGE

Storage Conditions

Hay storage conditions may be variable across any geographical region, but in general, the costs involved in preparing a storage area determine the type of storage system to be used. Similarly, the physical features of the hay (baled, stacked, pelleted, etc.) determine whether or not the storage area has to be protected from the weather. Environmental conditions, primarily rainfall, can cause a considerable loss of nutrients as well as partial loss of dry matter. Basically, "hay-barns" offer only weather protection and do not control or compensate for losses of nutrients or dry matter associated with the hay's moisture content at storage.

Percent moisture of hay at storage is directly related to nutrient and dry matter losses. Moisture conditions that permit hay to undergo heating result in greatest losses. The degree of heat that develops during storage depends not only upon the moisture of the hay but also on the density, size, and shape of the storage mass and the amount of surface area exposed (Musgrave and Kennedy, 1950). Spontaneous combustion is a potential problem with storage of high moisture hay, whether baled or in bulk. Internal heating increases with bale density and moisture content. Moisture content of stored hay is the main factor controlling nutrient retention in storage (Nelson, 1966). Bales stored at higher moisture content also are subject to mold.

Hay harvesting equipment has been improved during the past decade. One of the main objectives in the development of new machinery and mechanization systems has been to minimize hand labor requirements and to stabilize or decrease nutrient and dry matter losses from harvesting until feeding. Some of these systems incorporate the use of large bales or compressed stacks to achieve these goals (Figure 7-4).

Figure 7-4. Types of hay packages used in feeding studies at Overton.

Nutrient Losses in Storage

The remainder of this chapter is based on a hay storage and feeding experiment at The Texas A&M University Agricultural Research and Extension at Overton, Texas. Coastal bermudagrass, fertilized with 200-100-100 (N-P_2O_5-K_2O), was cut on October 5, 1971, when 7 weeks old and compressed in stacks on October 7 using a Hesston Stakhand 30. All stacks, approximately 8 feet wide x 14 feet long x 9 feet high at stacking, were stored outside and unprotected from the weather.

The nutrient status of the conserved hay was monitored from harvest to feeding. Percent in vitro digestible dry matter (IVDDM) declined 9.6 percentage units. This represented a change of 18.6 percent between time of cutting and time of stacking (Table 7-4).

Table 7-4. Nutritive status of Coastal bermudagrass hay at cutting and during storage in compressed stacks, Overton, Texas.

Time of Sampling	Protein (%)	IVDDM[1] (%)
At cutting (Oct. 5)	11.1	51.6
At stacking (Oct. 7)	8.9	42.0
In storage (Nov. 23)	8.9	34.1
As fed (Jan. 10 to Mar. 2)	8.9	32.4

[1] In vitro digestible dry matter

Since this nutrient loss occurred during field drying, the decrease in digestibility was completely independent of the method of hay storage. Moisture content at stacking was 25 percent. Thus, had the hay been allowed to sufficiently field cure to bale, a higher nutrient loss during curing would have been expected. During a 47-day period following stacking (Oct. 7 to Nov. 23), IVDDM declined 7.9 percentage units, or a change of 18.8 percent. Chemical analyses of a separate group of hay stacks indicated that most of the nutrient losses in storage occurred with moisture loss immediately after the stacks were formed.

Percent protein declined 2.2 percentage units from time of harvest to time of stacking. This loss represented a 19.8 percent change. Percent protein remained relatively constant throughout the storage period. Facilities were not available to measure dry matter losses of the hay during storage. Other work has shown that dry matter losses of hay stored at 25 to 30 percent moisture usually do not exceed 5 percent (Musgrave and Kennedy, 1950).

Since hay harvesting was conducted by a custom operator, hay could not be baled at the same time that it was stacked. Other research has shown that baled hay does not have as high a nutrient loss in storage as stacked hay (Bartle and Voelker, 1970).

FEEDING

Expenses involved in feeding any conserved forage, especially hay, are determined to a large extent by: (1) nutritive value of forage fed (the higher the nutritive value, the less dry weight required by animal), and (2) forage waste. Both factors can be controlled to some degree by proper management decisions. The amount of hay that is wasted or refused in the feeding operations is of primary concern because all harvesting and storage costs are fixed on a weight or volume basis. Waste is a function of the amount of hay offered per animal per unit time. The quantity of hay offered is in turn influenced by the physical form of the hay mass. Waste may be controlled very closely by hand-feeding baled hay. This reduction in waste, however, may be offset by associated labor costs. On the other hand, hay fed as loose stacks (1000 - 6000 pounds) reduces labor requirements but may increase percent waste.

Waste

Another objective in the stacked hay-nutrient loss study was that of estimating percent waste of hay fed as bales and as loose stacks. Twenty F-1 (Hereford x Brahman) cows, their 1/2 Brown Swiss calves, and 1 bull were assigned each to a baled hay group and a stacked hay group. A cow + calf is referred to as an animal unit. Cattle in the stacked hay group were allowed access to one stack at a time and were allowed to consume hay *ad libitum*. Baled hay was fed on the ground, and the number of bales fed was adjusted so that consumption was complete in a 2-day period. Waste from the baled hay group was approximately 3 percent (Table 7-5). Hay waste from the stacked group ranged from 18 to 25 percent (Table 7-6).

Table 7-5. Percent waste from feeding baled hay, Overton, Texas.

Date	No. Animal Units	No. Bales Fed	No. Days on Bales	Dry Matter[1] Fed	Dry Matter[2] Waste	Waste
				(lbs)	(lbs)	(%)
2-11	20	23.0	2	920	26.4	2.9
3-03	22	26.0	2	1,040	24.1	2.3
Avg.	21	24.5	2	980	25.3	2.6

[1]Average oven-dry weight per bale was 40 lbs.

[2]Waste shown is hay. Manure was not part of the dry matter weight.

Table 7-6. Percent waste from feeding Coastal bermudagrass stacked hay, Overton, Texas.

Stack No.	No. Animal-Units	No. Days Fed	Total Dry Matter/Stack[1]	Dry Matter Hay Waste	Hay Waste[2]
			(lbs)	(lbs)	(%)
7	21	6	4,536	835	18.4
12	21	6	4,536	1,190	26.2
13	21	6	4,536	1,158	25.5
Avg.	21	6	4,536	1,061	23.4

[1]Dry matter weights represent an average of two stacks weighed at time of storage.

[2]Expressed as a percent of total dry weight of stack.

One of the primary factors that influenced waste from stacked hay was the amount of "lounge-time" the animals spent on the hay. Separation of refused hay from manure showed that the hay waste was 33 percent manure. Animals will bed, urinate, and defecate on the hay stack site once they have consumed one-half to three-fourths of the hay mass. Some practices that may be incorporated to minimize waste from feeding stacked hay are: (1) Adjust number of animals allowed to feed from a stack. By increasing the number of animals per stack, there will be more competition between animals for hay; hence, more time will be spent feeding from the stack and less time lounging on the hay. In addition, the broken stack will not be exposed to the environment for any lengthy period. Waste from feeding stacked hay may be as high as 40 percent, if climatic conditions are conducive to excess trampling and spoilage (Renoll et al., 1971); (2) Limit the time allowed to feed from the stack. Allow animals to have access to the stack only on some regular time interval (alternate days, one-half day, etc.). In this situation, some labor expenditures would be substituted for hay waste; (3) Force animals to consume normally refused hay. The type of livestock (weaner calf, dry cow, cow-calf, etc.) being used predetermines to a large extent the length of time animals may be forced to consume the hay residue. If weight fluctuations and weight losses are to be minimized, this approach may not be appropriate; (4) Use of a stack protector or stack guard (Figure 7-5). Hay waste from a stack enclosed by Stroberg stack guard panels was less than 5 percent. Once again, labor and fixed costs may offset the amount of hay that is not lost as waste.

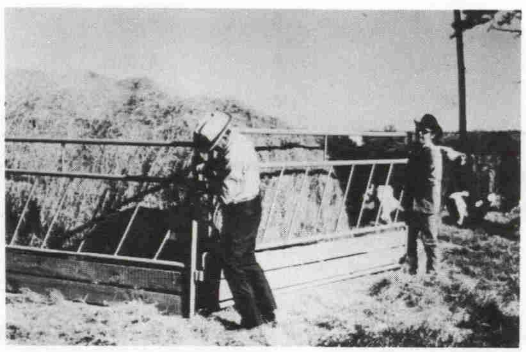

Figure 7-5. Compressed hay stack surrounded by guard to reduce hay waste during feeding at Overton.

ANIMAL UTILIZATION

Intake

Estimated dry matter intake was greater for animals with free access to stack hay than for animals fed baled hay (Table 7-7). Because each stack could not be accurately weighed, an average weight of two stacks was used for all hay stacks. Thus, intake values for animals in the stacked group are estimated and are not precisely measured values. Consumption per animal-unit was greater for animals on hay stacks. This trend is expected when cattle have complete access to stacked hay and when baled hay is fed on a restricted basis.

Table 7-7. Estimated daily dry matter intake of animals. Overton, Texas.

Type of Hay	No. Days Fed	No. Animal-Units Fed	Hay Consumed[1]	Intake/Day/ Animal-Unit	Intake/Day/ Cow[2]
			(lbs)	(lbs)	(lbs)
Bales	2	20	894	22.4	19.4
	2	22	1,016	23.1	20.1
	Mean	21		22.8	19.8
Stacks	6	21	3,701	29.4	26.4
	6	21	3,346	26.6	23.6
	6	21	3,378	26.8	23.8
	Mean	21		27.6	24.6

[1]Estimates of hay consumption were made by the following calculations: (Hay offered - Hay waste = Hay consumed).

[2]Calf daily dry matter intake was estimated to be 3 pounds per day (1.5% body weight) and was subtracted from the animal-unit intake.

An estimated daily nutrient intake also was calculated (Table 7-8). In addition to hay, both groups received 3 pounds per animal-unit per day of a 20 percent protein range cube supplement to provide a diet that would be near-adequate for rebreeding purposes. The estimated daily nutrient intake showed that both baled and stacked hay diets were energy-deficient. Estimates of protein intake indicated a slight excess of digestible protein in the hay-supplement ration. A large proportion of the hay baled in Texas is in the same category as the hay used in this study. In these hays, digestible energy is usually deficient, and digestible protein is usually in excess of the requirements of the animal. Thus, it becomes readily apparent that energy, not protein, may be required to supplement cattle fed total hay rations. (See Chapter 8 for additional information on nutritive value of Texas hays.)

Table 7-8. Estimated daily nutrient intake from hay and supplement, Overton, Texas.

	Source of Hay	
	Bale	Stack
Dry Matter Intake Per Cow (lbs)	19.8	24.6
Digestible Protein (lbs)		
Hay	1.5	1.4
Supplement	0.4	0.4
TOTAL	1.9	1.8
Deviation from NRC requirements[1]	+0.7	+0.6
Total Digestible Nutrients (lbs)		
Hay	9.2	8.9
Supplement	2.0	2.0
TOTAL	11.2	10.9
Deviation from NRC requirements[1]	-1.1	-1.4

[1]National Research Council (NRC) daily requirements for a 992-lb lactating cow during the first 3-4 months postpartum are 1.17 lbs digestible protein and 12.34 lbs total digestible nutrients.

Animal Performance

Both groups of cattle were placed on a hay-supplement diet on December 15. A 3-week adjustment period (Dec. 15 to Jan. 7) was allowed prior to initiation of the loss-gain account of the cows and calves. During a 60-day period (Jan. 7 to Mar. 7), cows in both groups lost approximately one pound per head per day (Table 7-9). Calf gains from the baled hay group slightly exceeded those from the stacked hay group. Hay conserved as bales was higher in nutritive value at feeding (protein = 11 percent; IVDDM = 45 percent) than hay conserved as stacks. Therefore, even though animals on baled hay consumed less total dry matter, the total nutrient status of the baled hay ration was slightly superior to that of the hay stacked diet. The nutrient status of both groups was sufficient to provide 95 percent rebreeding of all cattle on test.

Table 7-9. Animal performance from feeding baled and stacked hay, Overton, Texas.

	Baled Hay	Stacked Hay
Feeding Period	Jan. 7 to Mar. 7 (60 days)	Jan. 7 to Mar. 7 (60 days)
Cows		
Average weight[1] (lbs)	981	1,024
Average daily loss (lbs)	-0.99	-1.15
Calves		
Average weight[1] (lbs)	205	212
Average daily gain (lbs)	1.70	1.55

[1]Average weight of animals on test was calculated as (Initial Weight + Final Weight ÷ 2)

ECONOMIC COMPARISONS

Data from this investigation reveal that only after an economic appraisal can a choice be made whether to conserve hay as bales or stacks. An economic comparison between these two methods of storing and feeding hay is shown in Table 7-10.

Table 7-10. Costs involved in producing, harvesting, and feeding hay, Overton, Texas.

		Baled Hay	Stacked Hay
Production costs[1]	(per lb dry matter)	0.35 ¢	0.35 ¢
Harvesting - storage[2]	(" ")	1.00 ¢	0.66 ¢
Feeding[3]			
Loading and unloading[4]	(" ")	.0963¢	0
Travel time[5]	(" ")	.055 ¢	0
Panel time[6]	(" ")	0	.012 ¢
Cost/2-day period	(" ")	1.501 ¢	---
Cost/6-day period[7]	(" ")	1.804 ¢	1.022 ¢
Cost/cow-calf unit/day[8]	(" ")	42.95 ¢	36.79 ¢

[1]Production costs based on $7.00/ton of dry matter.

[2]"Custom" rates were 40 cents/bale stored in barn and $30/3-ton stack stored in field. Dry matter bale and stack weights at feeding were 40 lbs and 4500 lbs, respectively.

[3]Feeding costs based on hourly wage of $1.65.

[4]Time required for two men to load and unload 25 bales (1000 lbs dry matter) was 0.7 minutes/bale.

[5]Travel time during hay hauling and feeding period was 10 minutes.

[6]Time required for two men to move 4 metal panels was 10 minutes.

[7]Hay stacks fed animals for a 6-day period. Baled hay was fed for a 2-day period. Feeding costs [(.0963 + .055) x 3] + production costs + harvesting-storage costs equals cost/6-day period.

[8]Costs based on hay fed during a 6-day period. Cattle received 1000 lbs dry matter baled hay for a 2-day period. Cattle received 4500 lbs dry matter stacked hay for a 6-day period. There were 21 cattle/group.

Costs were computed on an oven-dry matter basis. In order to simplify the economic comparison, custom harvesting and storing rates were used; thus, machinery ownership was not a variable. Based on dry matter weights of bales and stacks at time of feeding and on the estimated feeding waste of each system (bales = 2.6 percent, stacks = 23.4 percent), there was a 6-cent/head/day advantage in favor of stacked hay. However, numerous factors can alter the feeding costs of each system, which in turn would serve to increase or decrease the cost advantage of stacked hay. The primary factors involved are: (1) weight of bales, (2) hand labor costs, (3) travel time in feeding, (4) number of cattle to be fed, and (5) percent wastes from each system.

Table 7-11 shows one of the many alternatives in computing hay feeding costs with bales or stacks. This information is based on a oven-dry bale weight of 60 pounds at feeding and a reduction in waste in feeding stacked hay from 23.4 percent to 10 percent. A 60-pound bale versus a 40-pound bale would reduce the number of bales per feeding by one-third, and it is assumed that handling time per bale would be constant. Hay waste could be reduced by increasing the number of animals per stack, which would not increase feeding costs. Under these conditions, cost advantage to feeding stacked hay is slight. But total costs per head per day were reduced 60 - 24 percent under these assumptions. Such reductions in costs of wintering cattle determine the profit that is to be made on the weaned calf crop. A detailed cost analysis of methods of conserving forage is presented in Chapter 14.

Table 7-11. Estimated feeding costs using 60-pound bales and stacks with 10 percent waste, Overton, Texas.

		Baled Hay	Stacked Hay
Production costs[1]	(Per lb dry matter)	0.35 ¢	0.35 ¢
Harvesting - storage[2]	(" ")	0.667 ¢	0.66 ¢
Feeding[3]			
Loading and unloading[4]	(" ")	0.0642¢	0 ¢
Travel time[5]	(" ")	0.055 ¢	0 ¢
Panel time[6]	(" ")	0 ¢	0.012 ¢
Cost/2-day period	(" ")	1.136 ¢	
Cost/6-day period[7]	(" ")	1.375 ¢	1.022 ¢
Cost/cow-calf unit per day[8]		32.74 ¢	30.91 ¢

[1]Production costs based on $7.00/ton of dry matter.

[2]"Custom" rates are 40 cents/bale stored in barn and $30/3-ton stack stored in field. Dry matter bale and stack weights at feeding are 60 lbs and 4500 lbs, respectively.

[3]Feeding costs based on hourly wage of $1.65.

[4]Time required for two men to load and unload 17 bales (1000 lbs dry matter) was 0.7 minutes per bale.

[5]Travel time for hauling and feeding bales was 10 minutes.

[6]Time required for two men to move 4 metal panels was 10 minutes.

[7]Average feeding time per stack was 6 days. Baled hay was fed for a 2-day period. Feeding costs [(0.0642 + .055) x 3] + production costs + harvesting-storage costs equals cost/6-day period.

[8]Costs based on hay fed during a 6-day period. Cattle received 1000 lbs dry matter baled hay for a 2-day period. Cattle received 4500 lbs stacked hay for a 6-day period. A 15 percent reduction in waste of feeding stacked hay permitted 4 more cow-calf units (total of 25) to feed from stacks during 6-day period. Twenty-one units remained on the baled hay group.

SUMMARY

Forage conserved as hay has been and will continue to be an important part of the plant-animal enterprise. The flexibility and feed efficiency potential of hay has been recognized but has not yet been utilized to its fullest extent. The high energy requirements to remove large amounts of moisture from fresh-cut forage make it difficult to find economical artificial drying methods. Therefore, the initial moisture content and field drying rate of forages are two important physical properties.

Any method of harvesting forage crops that reduces field drying time is important because quality deterioration is directly related to field exposure time. Tests show that little advantage is gained by using hay conditioners to reduce the moisture content of alfalfa to 50 percent. However, when it is necessary to reduce the moisture to 25 percent, the crusher used in conjunction with the conventional method of making hay saves 14 hours drying time. The hay conditioners significantly reduce the field drying time when sudangrass is dried to both 50 and 25 percent moisture content.

Results of tests conducted to develop improved methods of drying forages indicate that the difference in drying time required for flamed and unflamed alfalfa is insignificant. However, a saving of 20 hours results in field drying flamed, conditioned (crushed) alfalfa as compared to unflamed, unconditioned alfalfa.

When single layers of hay are exposed to infrared energy, studies show that the higher the radiation intensity and the longer the exposure period, the greater the rate of moisture removal. One major problem encountered in this type of drying is scorching of the leaves.

The application of heat and pressure does not alter the drying characteristics of alfalfa. A significant decrease in drying time has been obtained, however, when alfalfa is frozen by different methods prior to drying.

The trend in hay making will be toward storage and conservation methods that minimize both cash costs (hand labor) and fixed costs (storage buildings) as well as dry matter and nutrient losses. A substantial increase in the amount of forage that is pelleted is expected because of improved quality conservation and increased number of

confined animals. On a much larger scale, however, the trend in hay making will be oriented toward conserving forage in larger and heavier units than the standard bale and storing these units outside, unprotected from the weather. The size and shape of these hay units will be determined largely by herd size. A more widespread use of various preservatives during harvesting and/or storage will occur as a means of reducing the tremendous losses during field drying and storage.

Furthermore, production costs, primarily for fertilizer, will eliminate the practice of using a perennial grass stand exclusively as a "hay meadow". Rather, stocking rates or grazing management practices will be adjusted during peak production periods to allow hay to be harvested from a part of the pasture.

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