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Hay Handling System Comparison (Baled Hay Vs Chopped Hay)

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INTRODUCTION

Meyer (8) recently completed a comparison of two hay handling systems—baled hay cured in the field and chopped hay stored at about 40 percent moisture content and dried in the barn with unheated air. Hopefully, the information from his study—when added to existing evidence—will help with handling system selection. The study was conducted on a University dairy farm near Columbia, Missouri.

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STORAGE STRUCTURES

Storage structures included a 50 ft. by 70 ft. pole frame building for baled hay and, for chopped hay, an experimental 60 ft. by 60 ft. building with adjoining free-stall loafing sheds. Fig. 1 is a top view of the chopped hay structure. Fig. 2 is a sectional view of only the hay storage area and feeding alleys.

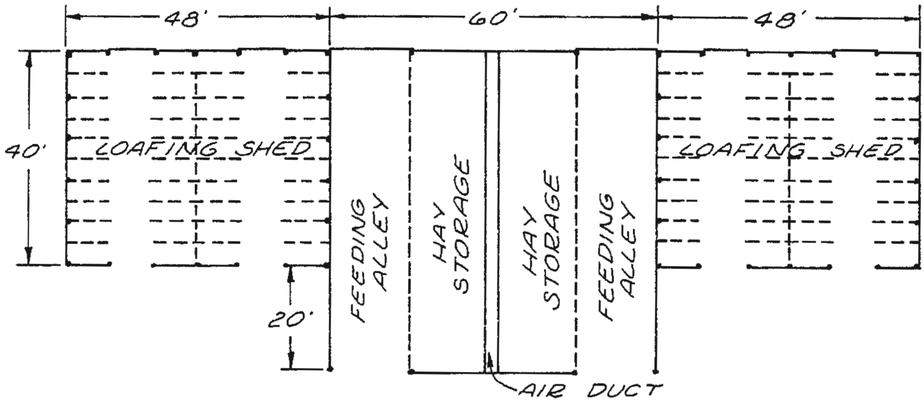

Figure 1. Top view of chopped hay storage structure and adjoining loafing sheds

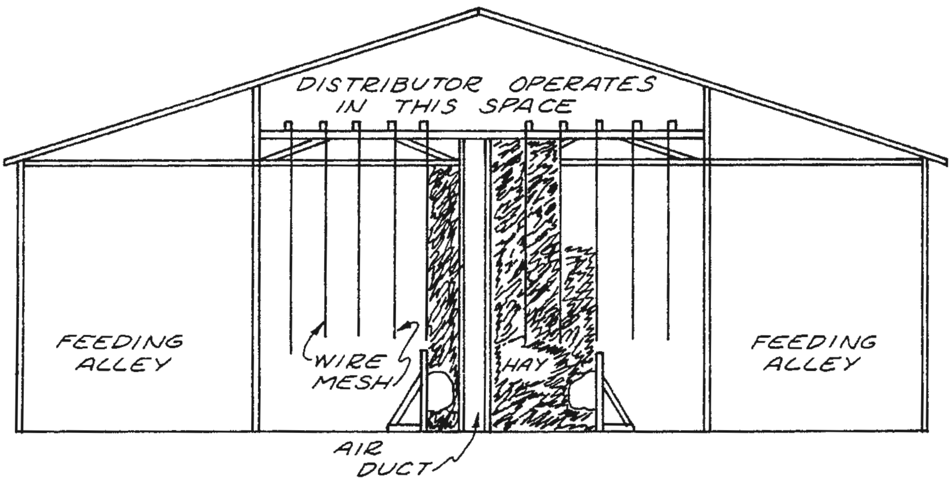

Figure 2. Sectional view of chopped hay storage area and feeding alleys

Chopped hay was stored by means of a flight elevator and overhead distributor. Figs. 3 and 4 show the elevating and distributing mechanisms. This method of handling chopped hay requires considerably less power than a forage blower. An added advantage is that very little separation of forage particles occurs as the hay is stored.

Figure 3. Elevating chopped hay into storage

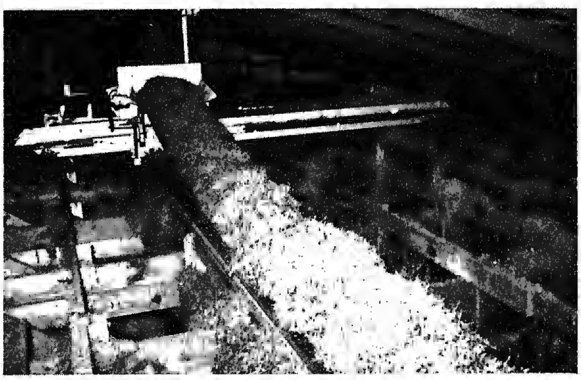

Figure 4. Chopped hay distributor

Wire mesh cleavage planes were incorporated into the basic structure of the experimental chopped hay barn to prevent bridging and facilitate self-feeding. The wire mesh and supporting members are visible in Fig. 4. The wire mesh, which is suspended from the top of the storage area to within six feet of the floor, allows movable feed bunks to be positioned under the wires as additional sections of hay are fed.

One of the primary advantages of the chopped hay system is that a greater amount of dry matter is preserved by reducing the time the hay must be exposed to the elements in the field. This is accomplished by cutting the hay early in the morning of the day it is to be harvested, allowing it to field cure to approximately 40 percent moisture, harvesting with a field forage chopper, and finishing the curing process in storage with an unheated forced air drying system.

MACHINE SYSTEMS

The machine system components and labor requirements for each hay handling method are listed in Table 1 and Table 2 respectively.

TABLE 1. MACHINE SYSTEM COMPONENTS

System	Machine	Number	Function
Chopped (40%)	Windrower (pull-type)	1	Mow, condition
	Tractor (64 pto Hp)	1	Power windrower
	Side-Delivery Rake	1	Rake hay
	Tractor (35 pto Hp)	1	Power Rake
	Chopper (self-propelled)	1	Chop hay
	Forage Wagons	3	Haul chopped hay
	Truck (4-wheel drive pickup)	1	Tow forage wagons
	Tractor (76 pto Hp)	1	Power wagons to unload
	Elevator	1	Elevate chopped hay
	Overhead Distributor	1	Distribute chopped hay in barn
	Fan	1	Dry chopped hay
Baled (25%)	Windrower (pull-type)	1	Mow, condition, windrow
	Baler with Bale Ejector	1	Bale and load hay
	Tractor (64 pto Hp)	1	Power windrower and baler
	Baled Hay Wagons	3	Haul baled hay
	Tractors (64 and 76 pto Hp)	2	Tow bale wagons
	Truck (pickup)	1	Feed baled hay

TABLE 2. LABOR REQUIREMENTS

System	Operation	Men Required
Chopped (40%)	Mow, condition	1
	Rake	1
	Chop	1
	Haul hay to storage	1
	Unload wagons	1
	Operate elevator and overhead distributor	1
	Feed hay (move stanchions infrequently during storage)	1
Baled (25%)	Mow, condition, windrow	1
	Bale	1
	Haul hay to storage	2
	Store hay	3
	Feed hay	2

PROCEDURE

Harvesting the Samples

To determine harvesting differences between the two systems, two 4.5 acre plots were staked out in a uniform stand of second cutting alfalfa. A one-acre plot was also staked out for yield and field loss determinations. The 4.5 acre plot to be harvested as field-cured baled hay was cut immediately after the chopped-hay plot was cut. By cutting both plots the same morning, differences in yield and maturity were minimized. Information reported by Hundtoft (6) indicates that if hay is field cured, quality of hay cured in a windrow is better than that cured in a swath. An effort was made to harvest the baled hay by the field-curing method which would yield the highest quality product. The baled hay plot was cut, conditioned and windrowed in one operation with a pull-type windrower. Based on findings by Halyk and Bilanski (5) that hay dries more rapidly in a swath than in a windrow, the plot to be harvested by the chopped hay system was cut, conditioned and left in a swath. Frequent moisture samples were taken using portable oil-distillation equipment.

Yield and field losses were determined from a one-acre plot adjacent to the two experimental plots. This plot was cut immediately after the experimental plots to minimize yield and maturity differences among the three plots.

The theoretical cutting width of the windrower was nine feet. By making the yield and field losses plot exactly 484 feet long, one trip with the windrower harvested exactly one-tenth acre. To insure that the theoretical width of the windrower was always being used, the inner edge of the cutterbar was held approximately one and one-half feet into the standing crop. A cutting height of two inches was held constant by skid shoes mounted directly behind the cutterbar.

To determine yield and harvest losses, the windrower traveled the length of the plot seven times. Three trips—replications of the method used to cut and condition experimental chopped hay—were made through the plot with the deflectors on the windrower in the open position, allowing the cut and conditioned material to return to the ground in a swath. Three additional trips—replications of the method used to cut, condition and windrow experimental baled hay—were made through the plot with the deflectors in the closed position, forming windrows. Finally, one trip was made through the plot with a tarpaulin suspended behind the conditioning rolls to catch all the material that passed through them for yield determination. The header mechanism on the windrower was so arranged that all of the material passing over the cutterbar also passed through the conditioning rolls. Fig. 5 shows the windrower with the tarpaulin suspended behind the conditioning rolls to catch the hay for yield determination. The material collected on the tarpaulin was loaded onto a truck, weighed and sampled for moisture. The dry matter content of material removed from the one-tenth acre plot was considered the maximum obtainable yield. All field losses were calculated as a percentage of the maximum obtainable yield.

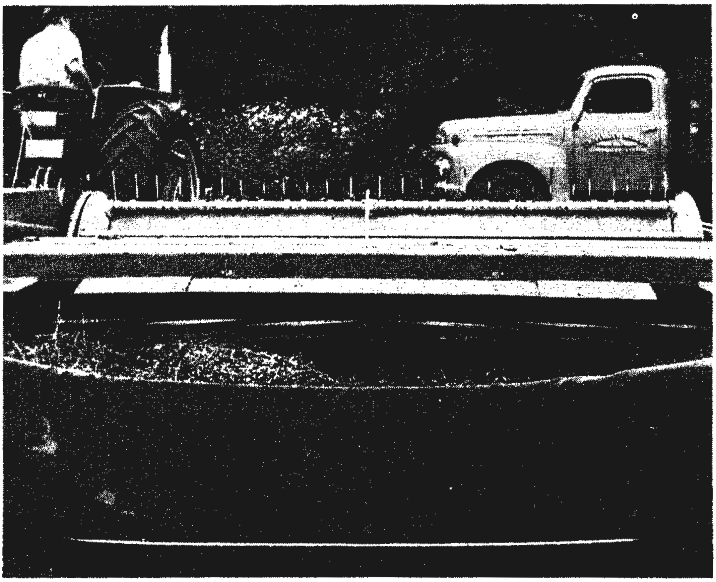

Figure 5. Windrower with tarpaulin for yield determination

The three field loss replications for the experimental chopped hay system were harvested immediately after harvesting the 4.5 acre experimental hay plot. Each replication was chopped onto a separate wagon. These wagons were weighed and three random samples were taken from each wagon for moisture determination. The three field loss replications for baled hay were determined in a similar manner.

Processing the Samples

All samples that were to be oven dried for moisture determination or for chemical analysis were sealed in one gallon plastic bags at the time they were taken. As soon as possible after samples were taken, they were weighed and placed in a forced-air electric oven to be dried. To prevent protein breakdown, the maximum oven temperature was limited to 100°F. Samples to be analyzed chemically were resealed in the plastic bags and sent to the University of Missouri - Columbia Agricultural Experiment Station Chemical Laboratory for moisture, crude fiber and nitrogen analysis.

Storage losses were also determined for both systems. Every fifteenth bale stored was taken as a sample from the baled hay plot. Each bale was tagged for identification and a sample was removed from each bale for moisture determination and chemical analysis. These samples were taken with a tube coring device similar to one originally developed by Baylor (2). After these samples were removed, the bales were weighed and stored. At the end of a seven-week storage period, each bale again was weighed and a second core sample was taken from the opposite end of each bale. The dry matter weight of each bale going into and coming out of storage was computed with the difference representing the amount of dry matter lost during storage. Samples taken before and after storage were also analyzed chemically for loss of nutrient matter.

The chopped hay storage losses were determined by a similar process. From each wagon load of chopped hay going into storage, two large samples were taken at specified intervals. These large samples were each divided into two smaller samples. One sample of approximately 500 grams was placed in a lightweight muslin bag. The second sample of about 200 grams was sealed in a one-gallon plastic bag. Corresponding numbers were placed on the muslin bags and the plastic bags for identification. The muslin bags were placed in the hay mass along with the loads of hay from which they were taken. The samples in plastic bags were oven dried for moisture determination. At the end of a seven week storage period, the muslin bag samples were removed from storage, weighed and dried. The amount of dry matter stored and the amount removed from storage were computed. The difference represented the amount of dry matter lost in storage. All samples were analyzed chemically to determine the loss of nutrients in storage.

Feeding Trial

A feeding trial with dairy cows was conducted to determine the amount of fat-corrected milk produced per pound of forage dry matter consumed and to get an indication of the voluntary intake of both types of hay. Eight Holstein cows were selected from the regular milking herd at the dairy farm. These cows were paired into two groups of four cows each, based on body weight and milk production. To facilitate a gradual adjustment from green forage on pasture to dry hay in confined stalls, the cows were placed on an eight day adjustment period. Fig. 6 shows the cows in the tie-stall barn where the feeding trial was conducted.

Figure 6. Cows in feeding trial

A 10-day check period followed the adjustment period. Each cow was fed one pound of concentrate for every four pounds of milk produced. This amount of concentrate was not varied with production fluctuation during the check and experimental periods. Cows to be fed the experimental baled hay were fed baled alfalfa hay supplied by the farm herdsman during the check period. This was not research hay. Cows to be fed experimental chopped hay were fed alfalfa hay identical to the hay fed the other group. However, to insure that differences between the check period and the experimental period for those cows fed chopped hay could not be attributed to the difference in physical size and density of chopped hay versus baled hay, the bales were broken and hand fed through a field forage chopper. This resulted in hay for the check period that was of equal nutritive value; however, it conformed to the physical properties of the experimental baled and chopped hay to be fed during the second phase of the trial.

Following the check period, the experimental hays were fed for 20 consecutive days. The average body weight for each group of cows was determined for each period by weighing them individually on a small platform scale. The cows were weighed immediately after the morning milking at regular intervals during both the check and experimental periods to obtain an average weight per period. The milk produced was weighed with a milk metering device and recorded after each milking. Milk samples were periodically taken and sent to the Dairy Husbandry Department for butterfat analysis by the Babcock Method.

The amount of hay fed, eaten and rejected by the cows was determined twice daily. All cows were intentionally fed approximately 20 percent more hay than they would normally eat during both the check and experimental periods to get an indication of voluntary intake. Overfeeding by 20 percent allowed the cows to satisfy their appetites for forage without having to eat the less acceptable portions of their daily forage ration. A comparison of pounds of forage dry matter consumed per pound of body weight for each group of cows should indicate which, if either, forage was more acceptable.

Motion and Time Studies

Motion and time studies were conducted on the harvesting, storing and feeding phases of both hay harvest systems. Harvesting operations were divided into five time elements: the actual time the machines were performing the harvesting function, the time required for hitching and unhitching wagons, the time required for turning and traveling between windrows, the time required for mechanical repairs and adjustments, and the time harvesting machines were required to wait on other operations and machines in the system.

Time for storage was divided into the following five elements: the actual time required for moving hay into storage, for hitching and unhitching wagons, for positioning wagons at the storage structure, for mechanical repairs and adjustments, and the time men and machines were required to wait on other operations and machines in the system.

The time for feeding baled hay was divided into the three following elements: getting ready for the feeding operation, loading and transporting hay from the storage structure to nearby feed bunks, and feeding the hay.

The time for feeding chopped hay was divided into only two elements: the time required to remove the small amount of unpalatable hay that cows refused to eat ahead of the self-feeding stanchions and the time required to move the stanchions forward.

Time required to dispose of the hay removed from the stanchions was not recorded because this hay was thrown into the lot and later removed along with the normal manure disposal.

RESULTS

Nutrient Analyses

Different levels of moisture have considerable influence on the cost per ton of forage handled. It is the dry matter content of forages from which animals can derive usable energy and from which economic returns can be expected. Because animal output depends primarily on the amount of dry matter in a given weight of forage, handling costs should be based on dry matter content rather than wet weight. It seems improper to compare the cost of handling a wet ton of hay at 40 percent moisture content with hay at 25 percent moisture content since the dry hay contains 400 pounds more dry matter per wet ton than does the wet hay. Since many of the operations compared in this study involved handling hay at significantly different moisture levels, all data has been converted to a dry matter basis.

Total dry matter losses and total digestible nutrient losses for field and storage operations for both systems are summarized in Table 3. The total digestible nutrient content was computed as follows: TDN = (71.72-0.47 (Crude Fiber)) (Dry Matter). Due to a heavy rain shower occurring late in the afternoon and evening of the date the hay plots were cut, field losses were high. The difference in moisture content at the time of the rain was probably responsible for the extreme difference in field losses of nutrient matter. The hay to be chopped had been placed in a swath and had dried to 45 to 50 percent moisture at the time of the rain. The hay to be baled was placed in a windrow at the time it was cut and lost very little moisture before the rain occurred. This moisture difference, plus the fact that much more surface area of the hay to be chopped was exposed directly to the elements, caused the chopped hay to lose more nutrient matter.

The slightly lower loss of dry matter for the chopped hay system can be explained by the fact that the chopped hay was removed from the field at a higher moisture content than the baled hay. Leaf shattering was probably less on hay harvested by chopping.

TABLE 3. FIELD, STORAGE, AND TOTAL LOSSES OF DRY MATTER AND TOTAL DIGESTIBLE NUTRIENTS FOR BOTH HAY HANDLING SYSTEMS

System	Operations	Dry Matter Loss (Percent)	Calculated Total Digestible Nutrients (Percent)	Change From Maximum TDN (Percent)
Chopped (40%)	Field	4.14	52.85	5.01
	Storage	3.50	53.81	3.29
	Total	7.64		8.30
Baled (25%)	Field	6.95	54.30	2.41
	Storage	5.63	53.70	3.49
	Total	12.58		5.90

Time Efficiencies

Time efficiencies of machines and operations were determined as a ratio of the time effectively used to the time required to perform all functions of an operation. According to Hunt (7), the time effectively used, or theoretical field time, is the time a machine is operating at its full effective width at an optimum forward speed. In this paper, the term "theoretical operation time" will be used for operations out of the field, such as towing wagons from the field to storage, storing hay and feeding hay. Both field and operation efficiencies have been computed as the ratio of the theoretical time to the total operating time, which includes time required for field machines to turn at the ends of windrows, other unproductive travel across fields, hitching and unhitching wagons, making machine repairs and adjustments needed during normal operations and other necessary, but not productive, time-consuming activities. Machines and operation performances for both systems are shown in Table 4.

Although nearly all operation efficiencies for both systems were low compared to efficiency estimates by Hunt (7), there are indeed cases for all farm operations where mechanical failures and poorly coordinated harvesting, transporting and storing operations cause efficiencies similar to those observed in this study. It is not highly unusual for a field machine such as a baler or forage harvester to be inoperative for an hour or more on any particular day due to mechanical failures, adjustments or plugging conditions.

For this particular investigation, the forage chopper was inoperative for 0.823 hours due to one severe plugging condition which caused several protective shear pins to fail. The experimental, overhead chopped-hay distributor was inoperative for 1.122 hours. Breakdowns such as these in a machine system cause all other machines and operations to wait on the repair of these particular machines. Lowered field and operation efficiencies for all machines and subsequent

TABLE 4. MACHINE AND LABOR PERFORMANCE

System	Operation	Machine Hours Per Acre	Tons of Dry Matter Per Hour	Efficiency (Percent)	Men Working	Man Hours Per Ton of Dry Matter
Chopped (40%)	Cutting	0.362	3.583	---	1	0.279
	Raking	0.305	3.830	81.30	1	0.261
	Chopping	0.559	2.089	43.40	1	0.479
	Hauling	0.611	1.912	63.15	1	0.523
	Unloading	0.793	1.473	38.40	1	0.679
	Distributing	0.809	1.444	37.64	1	0.693
	Feeding	---	---	---	1	0.400
	Total					3.314
Baled (25%)	Cutting	0.341	3.326	---	1	0.301
	Baling	0.654	1.734	43.23	1	0.577
	Hauling	0.767	1.478	14.93	2	1.354
	Storing	0.760	1.492	15.53	3	2.011
	Feeding	---	---	---	2	1.006
	Total					5.249

operations are the result. Unless an entire system is highly coordinated, time efficiencies for all machines in a system will usually be lower than measured efficiencies for individual machines unhindered by less effective machines in the system.

The amount of time rendered unproductive due to machine failures for the baled hay system did not differ widely from the chopped hay system. A total of 1.164 hours was needed to correct a knotting mechanism malfunction for the baler.

The second cutting of alfalfa came at a time when the overall farm work load was light, resulting in a surplus of available labor. Having more men working than were actually necessary caused the manual operation of storing baled hay to be very inefficient.

Feeding Trial

Results of the feeding trial are shown in Table 5. It should be noted that the body weight of the group of cows fed the experimental chopped hay increased slightly more, as compared to weight during the check period, than the body weight of the group of cows fed the experimental baled hay.

The dry matter intake of the group of cows fed experimental chopped hay decreased while the dry matter intake of the group of cows fed experimental baled hay increased. This indicates that the experimental chopped hay was less acceptable than the experimental baled hay. Part of the differences in accept-

TABLE 5. AVERAGE DAILY CHANGES IN BODY WEIGHT, DRY MATTER INTAKE, AND MILK PRODUCTION PER COW

	Treatment	Period			
		Check (Pounds)	Experimental (Pounds)	Change (Pounds)	Percent of Check
Body Weight	Baled	1282.16	1307.55	+25.39	101.94
	Chopped	1191.66	1221.94	+30.28	102.48
Dry Matter Eaten	Baled	25.40	27.04	+ 1.64	106.09
	Chopped	22.69	21.01	- 1.67	92.64
Milk Produced (Fat Corrected)	Baled	34.35	33.14	- 1.21	96.46
	Chopped	32.52	29.61	- 2.91	91.04

ability can be attributed to the condition of the hay. The chopped hay molded slightly due to several power outages which stopped the drying fan. While the total milk production for both groups of cows decreased during the feeding trial, the decrease in dry matter intake of chopped hay resulted in a larger decrease in milk production for the group of cows fed the experimental chopped hay than for the group fed the experimental baled hay.

Annual Ownership Costs

The direct costs associated with harvesting, storing and feeding hay by both systems have been presented on an annual-cost-of-machine-ownership basis. Annual ownership costs include the labor required to operate the machines at the rate of $2.00 per hour.

All costs are based on harvesting and storing enough hay to feed a 90-100 cow herd of dairy cows. According to the Missouri Farm Business Planning Guide (9), a total of 375 tons of field cured hay or about 320 tons of dry matter is required annually for this size herd, including hay for replacement heifers.

Harvesting costs have been computed to include all costs incurred from the time the windrower entered the standing crop until the harvested forage was loaded onto wagons and towed to the storage structure. Field machine costs were computed from a modified version of an annual ownership costs equation developed by Hunt (7). In this equation both fixed and operating costs were considered. If an economic life of ten years is assumed, fixed costs can be accurately approximated as 15 percent of the new purchase price when straight line depreciation, interest on investment, insurance, shelter and taxes are considered. The new purchase price for all machines was based on 1967 manufacturer's list prices.

Operating costs include labor, fuel and oil, repair and maintenance, and tractor use costs. Since records were not available on repair and maintenance costs of individual machines, coefficients developed by Hunt (7) have been used to estimate these expenses for each operation. Different machines require different amounts of energy in the form of tractor power to operate them. To account varying power requirements, the cost for fuel and oil has been included in the operating cost for each implement rather than in the hourly use charge for the tractor. The amount of fuel and oil required per hour by various implements has been estimated by Bowers (4) and has been used to calculate the energy requirements for various implements.

A tractor use cost has been computed for all power units as follows:

$$\text{Annual Cost} = 0.15(P) + H_A\ (RM)\ (P)$$

where:

0.15—Fixed cost coefficient
P —New price (list)
H_A —Annual hours of use
RM —Repair and maintenance percentage

Based on an annual repair and maintenance cost of 1.2 percent of the purchase price per 100 hours of use, the annual ownership cost for one of the 64 horsepower tractors with a list price of $7437.20 and an assumed annual use of 1000 hours will be:

$$AC = 0.15(\$7437.20) + 1000(0.00012)\ (\$7437.20)$$
$$= \$2008.04$$

The hourly use cost then is simply the annual ownership cost divided by the annual hours of use. For the above tractor, this amounts to $2.01 per hour.

The modified equation for determining the annual ownership cost for field machines takes the form:

$$AC = 0.15(P) + H_A\ (RM)\ (P) + H_A(L) + H_A(T) + H_T(FO)$$

where:

0.15 = Fixed cost coefficient
P = New purchase price (list)
H_A = Actual annual hours of machine use (includes both productive and nonproductive time)
RM = Hourly cost of repair and maintenance as a percent of purchase price
L = Hourly labor charge
T = Hourly tractor charge (omitted if self-propelled, cost of electrical energy if electrically powered)
H_T = Theoretical efficiency (does not include time machine was idle)
FO = Hourly charge for fuel and oil.

As an example, the cost of cutting hay with the pull-type windrower will be computed. Based on recorded observations, the windrower will cut, condition and windrow enough hay to feed a 90-100 cow dairy herd in approximately 90 hours. The annual repair and maintenance cost is estimated to be 10 percent of the purchase price. If the windrower is 80 percent efficient, the annual cost of ownership will be:

$$AC = 0.15(\$2401.80) + 90(0.0010)(\$2401.80) + 90(\$2.00) + 90(\$2.01) + 72(\$0.70) = \$753.19.$$

The hourly cost will amount to $8.37. Operating at a capacity of 3.58 tons of dry matter per hour, the cost per ton of dry matter is $2.34. Harvesting costs for both systems are shown in Table 6.

Storage costs include all costs incurred from the time the loaded hay wagons arrived at the storage structure until the time the hay was removed from storage as feed.

Both hay-storage structures were built new in 1967. The pole-frame baled-hay barn cost $3,800 and has a capacity of about 240 tons of dry matter. The chopped-hay storage structure and adjoining loafing sheds cost $10,000. Since hay is stored in only part of this structure, only $6,000 of the total cost will be charged to hay storage, and the remaining amount should be charged to the dairy herd as shelter.

Annual ownership costs for the storage structures were computed as a percent of the new price of the structures. The depreciation, interest on investment, insurance, taxes, and repair and maintenance percentages were computed per dollar of new costs as follows:

$$\text{Depreciation} = \frac{\text{New Price—Salvage Value}}{\text{Economic Life}}$$

$$= \frac{P—0.1P}{15}$$

$$= 0.06P$$

$$\text{Interest on Investment} = \frac{\text{New Price} + \text{Salvage Value}}{2} \quad (0.06)$$

$$= \frac{\$1.00 + \$0.10}{2} \, (0.06)$$

$$= 0.033P$$

Insurance	= 0.003P
Taxes	= 0.006P
Repair and Maintenance	= 0.010P
Total Annual Cost	= 0.112P

A 15-year life was assumed for both the baled and chopped hay structures. Buildings are usually depreciated over a longer time than this, but since the interest in improving methods of handling forages is likely to cause early obsolescence, an economic life of only 15 years has been assumed. A salvage value of 10 percent of the new cost has been assumed to transfer a small part of the fixed cost to the enterprise for which the building is used after its economic life as a hay storage structure has expired.

TABLE 6. HAY HARVESTING COST

System	Operation	Annual Cost of Machine Ownership ($)	Estimated Annual Use (Hrs.)	Capacity Per Hour (Tons dry matter)	Cost Per Hour ($)	Cost Per Ton of Dry Matter
Chopped (40%)	Cut, condition	753.19	90	3.583	8.37	2.34
	Rake	458.58	90	3.830	5.10	1.33
	Chop	1692.94	160	2.089	10.58	5.06
	Haul	2066.98	175	1.912	11.81	6.18
	Total	4971.69			35.86	14.91
Baled (25%)	Cut, condition, windrow	753.19	90	3.583	8.37	2.34
	Bale	1813.85	185	1.734	9.80	5.65
	Haul	1166.82	215	1.478	5.43	3.67
	Total	3733.86			23.60	11.66

To store and dry enough chopped hay to feed 90-100 cows would require four complete chopped hay storage structures and overhead distributors comparable to the one used for this comparison. Two crop drying fans, provided they were portable and could be moved from one structure to another, could dry four barns of hay. The costs for these facilities, with all other storage costs for both systems, are shown in Table 7.

TABLE 7. HAY STORAGE COST

System	Operation	Annual Cost of Ownership ($)	Estimated Annual Use (hrs.)	Capacity Per Hour (Tons dry matter)	Cost Per Hour ($)	Cost Per Ton of Dry Matter
Chopped (40%)	Unloading and Elevating	149.94	215	1.473	3.15	2.14
	Distributing	1403.28	215	1.444	6.53	4.52
	Drying	601.64	1650	.199	0.36	1.81
	Storage	2688.00	--	---	--	8.40
	Total	4842.86				16.87
Baled (25%)	Unloading	(all labor)	--	1.492	6.00	4.02
	Storage	560.00	--	---	--	1.75
	Total	560.00				5.77

The costs per ton of dry matter stored seem excessively high for the chopped hay system. This is probably due to the higher initial cost of the more complex chopped hay storage structure. Also, chopped hay is less dense than baled hay, and a much larger building is required to store the same amount of dry matter. The chopped hay barn held only 80 tons of dry matter in a volumetric space of 32,400 cubic feet, resulting in a storage requirement of 405 cubic feet per ton of dry matter compared to only 272 cubic feet for baled hay.

Feeding costs per ton of dry matter were determined for both systems. Feeding baled hay by hand cost $2.58 per ton of dry matter. Labor costs for periodically moving the self-feeding stanchions amounted to about $0.80 per ton of dry matter.

The total harvesting, storing and feeding costs for both systems are shown in Table 8.

TABLE 8. TOTAL COSTS

System	Operation	Annual Cost of Ownership ($)	Cost Per Ton of Dry Matter ($)
Chopped (40%)	Harvesting	4971.69	14.91
	Storing	4882.86	16.87
	Feeding	---	.80
	Total	9854.55	32.58
Baled (25%)	Harvesting	3733.86	11.66
	Storing	560.00	5.77
	Feeding	--	2.58
	Total	4293.86	20.01

Conclusions

1. Data taken indicated better milk output from experimental baled hay than from experimental chopped hay. This difference may be accounted for by problems encountered while drying the chopped hay or the varying effects of rain on the windrowed and swathed forage during harvesting. The dry matter loss of chopped hay during harvest and storage was less than the dry matter loss of baled hay. Slacks and others (9) reported that more dry matter was preserved, and slightly more milk produced, from barn-dried chopped hay than from field-cured baled hay.
2. Man hours of labor required per ton of dry matter handled was less for the chopped hay system.

3. The fixed and operating costs per ton of dry matter were substantially lower for the baled-hay system when compared to an equivalent weight of hay handled by the chopped-hay system.
4. Since hay harvested by the chopped-hay system is removed from the field at a higher moisture content, the risk of sustaining weather damage for this system is lower than for the field-cured baled-hay system.
5. There is relatively little difference in quality of hay stored by the two methods. Choice of one method over the other will depend primarily on scarcity of labor and ability to justify ownership of additional machines by complementary use for other crops—such as using the field chopper and forage wagons for corn silage as well as chopped hay.

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