

# ECONOMIC BENEFITS OF WEATHER PROTECTION FOR LARGE ROUND BALES

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An economic evaluation of the storage losses of various haying systems is reported. This information was necessary to augment a study of the effect of storage characteristics on round bale quality in which round bales from two different round baler types (fixed and variable bale chamber) were stored in five different manners. In addition, the costs of harvesting and storing hay by several methods were evaluated. These costs were translated into costs per "useable" tonne of hay. Values of spoiled hay were compared with the values of weather protection for round bales. The values of hay spoilage in different types of storage were combined with detailed costs of growing, harvesting and storing hay and compared. Economic comparison with traditional rectangular bale harvesting methods is also included. It was found that round bale harvesting was the least expensive method at all volumes. Round bale harvesting with inside storage or plastic wrap protection provided a higher value than outside storage of round bales because of the increased spoilage when not protected. The cost of inside storage was equal to 14% spoilage of round bales.

## INTRODUCTION

The large round bale has become a familiar sight throughout the countryside in recent years. The ability to harvest hay with less labor and at a greater rate has held a great appeal to hay and livestock producers. They have been willing to sacrifice some quantity and quality of hay in order to reduce labor and increase productivity. Now there is some desire to avoid the quality and quantity losses without reverting back to the conventional rectangular bale.

In parts of North America where rainfall is significant, conventional rectangular bales are traditionally transported from the field to inside storage. Round bales and rectangular stacks were originally intended for outside storage in the dry regions of North America where even stacks of rectangular bales were stored outside. As the round baler moved into higher rainfall areas, increased spoilage was observed. Some farmers rejected the round bale stored outside, while others accepted the losses because of decreased labor requirements.

Many existing roofed storages suitable for rectangular bales are not suitable for round bales; hence if storages are to be used, they must first be constructed. Open-sided pole-supported roof structures are considered satisfactory protection for round bales. A great deal of user education has been disseminated indicating that if round bales are to be stored outside, they must be stored in a well-drained location with ample space between the bales to allow sufficient air circulation. A number of groups looked at covering or wrapping the round bale with plastic either as baled

TABLE I. CHANGES IN ALFALFA BALE QUALITY FOR THE SIX STORAGE TYPES

Storage type	Percent change in crude protein (%) from initial 24.3%	Percent change in digestible dry matter (%) from initial 64.4%
Barn	-17.9	-4.2
Wrap	-21.4	-12.2
Ground	-29.2	-23.4
Contact area cover	-29.3	-20.9
Projected area cover	-25.6	-24.0
Total ground cover	-27.7	-22.5

or after it was baled or when it went into storage to decrease spoilage (Rider et al. 1979; Verma and Nelson 1981). One company (M & M Gear Company) presented a method of wrapping the bale with plastic before it left the baler.

In 1981, a project was initiated by the School of Engineering at the University of Guelph to study the effect of storage characteristics on round bale quality. Round bales from two different baler types (fixed bale chamber and variable bale chamber) were stored in five different manners:

- outside on the ground, twine-wrapped
- outside on the ground, circumferential plastic-wrapped
- outside on a wooden pallet, twine-wrapped
- outside on a wooden pallet, circumferential plastic-wrapped
- inside a barn

A related exercise was initiated to estimate the costs of harvesting and storing hay by several methods. These costs were translated into costs per usable tonne of hay.

The objective of this study was to collect and analyze data on the costs of producing, harvesting and storing hay

in round and rectangular bales. Hay with different spoilage amounts was incorporated into the detailed costing to produce a cost of usable hay rather than just a cost of harvested hay. Rectangular bale harvesting methods were incorporated because they are a popular base for comparison.

## BACKGROUND

Numerous reports have been published indicating the amount of spoilage recorded in round bales. Moggach and Weeden (1979) indicate that round bale weathering losses in Ontario can range from 5 to 100% but that losses can be kept below 20% provided the bales are stored in a well-drained area with the bale rows at least 2 feet apart.

Currance and Matches (1976) indicate in their research in Missouri that sheltered storage is advantageous to maintain initial hay quality. In the high precipitation areas of Southern Louisiana, research indicated that storage of round bales of alfalfa and ryegrass in a barn or covered rack resulted in the lowest shrinkage, storage losses and change in quality and the highest digestibilities (Verma and Nelson 1981). The economics of providing cover for round bales is considered doubtful in Western

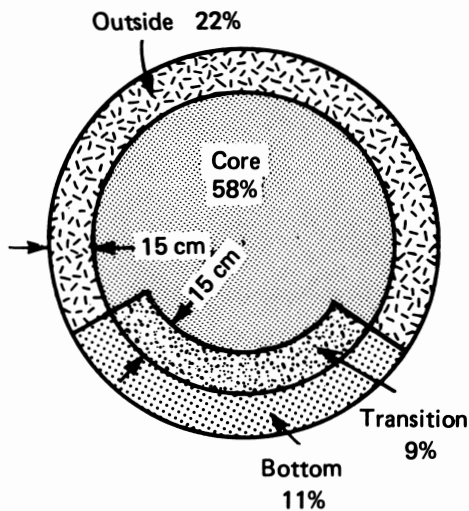


Figure 1. Round bale loss profile.

Canada where dry matter losses during outside storages of round bales are shown to be 4–8% (Friesen 1980). Storage of round bales in a building has been considered uneconomical in Ontario because of the inefficient use of space due to the limitation in piling them (Moggach and Weeden 1979). This study will show that the costs of covered storage can be less than the costs of outside storage in Ontario.

Rider et al. (1979) carried out extensive tests of six different storage conditions for large round bales formed from three species of hay. Total mass, dry matter content, moisture content, crude protein content and dry matter digestibility were monitored during the storage period. The results indicated that improved round bale storage methods increased the final quality. Storage methods were:

1. inside a barn;
2. unsheltered, with a black polyethylene wrap around the circumference of each bale;
3. unsheltered, with direct ground contact;
4. unsheltered, with black polyethylene under the bale contact area;
5. unsheltered, with black polyethylene under the projected bale contact area;
6. unsheltered, with a black polyethylene ground cover on the entire storage area.

The percent changes in alfalfa bale quality for the six storage types are shown in Table I. These results show that protected storage of round bales minimizes quality losses.

Rider et al. (1979) describe a method of sampling hay from a round bale in which specific areas of the bale represent

a certain percentage volume of the bale. They divide the bale into four areas as viewed from the bale end (Fig. 1).

Description of a round bale (Fig. 1) acknowledges a number of events that occur in storage:

- as a round bale settles, approximately one-third of the circumference contacts the ground;
- a substantial amount of moisture can be absorbed through the bottom of the bale resulting in spoilage as far up as 30 cm;
- if the weather affects only the outer 15 cm of a round bale plus an additional 15 cm at the bottom, 42% of the bale volume can be affected;
- assuming uniform bale density, the outer 15 cm of a round bale accounts for more than 20% of the mass.

This information demonstrates the importance of protecting round bales during storage.

Farm operators, like most businessmen, strive to ensure that the combination of input costs to a particular commodity or process are kept below the output value. Inputs usually consist of materials, machinery and labor, and are made up of a combination of fixed and variable costs (e.g., fixed — fertilizer, land, seed, etc.; variable — machinery, capital costs) such that as the activity level increases, the total input costs per unit of output decrease. The operator will strive to keep his input costs below the expected output value in order to provide sufficient return for his labor and management (Fig. 2).

If the maximum activity level is fixed (i.e., number of tonnes of hay required to feed the cattle), the operator will vary or change his inputs to ensure the best possible return. To do this, he must monitor input costs as they vary. Input substi-

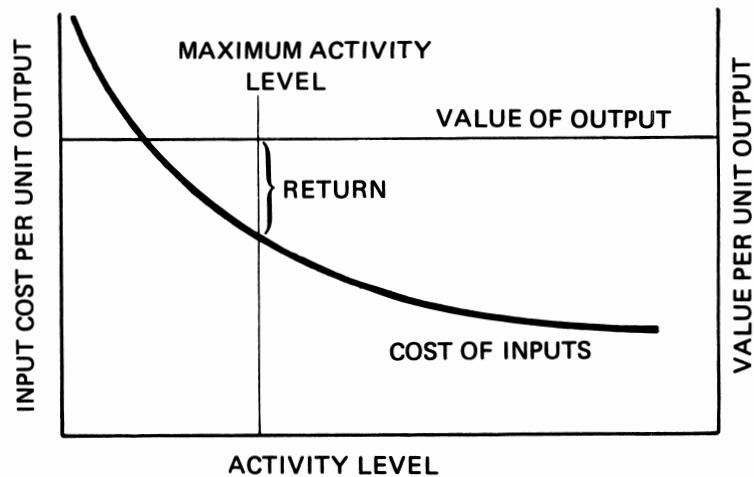


Figure 2. Production function curve and output value versus activity level.

tutions can be considered when determining input costs as long as the total costs and benefits of the two or more substitutive factors are clearly understood. Hay production and harvesting contain the above-mentioned inputs, outputs and potential input substitutions.

The large round baler was introduced to the marketplace not just as a direct input substitute for the square baler but as a means of displacing a significant amount of the necessary input labor. As the round baler spread through the market, a loss of output material value was noted (Parsons et al. 1978). This caused a shift in both the input cost and output value curves for hay production. Figure 3 compares input costs and returns for square bale and round bale conditions in which both round bale input costs and output values are lower than the corresponding values for square bales. Thus, in order to obtain the same minimum return, a larger activity level is required. Alternately, since a round bale system requires less of the farm managers labor and management, a lower return at the same original activity level may be acceptable.

In general, a round baling system results in decreased labor and management and a decrease in "out-of-storage" material quality. Most round bales have been stored outside and unprotected from the weather, resulting in reduced material quality and reduced material value. In time the actual material quality losses are becoming better quantified and there is a desire to return to the original quality level of inside stored square bales without increasing the labor input.

It is this portion of the original input substitution that this study investigates. At what cost and at what gain in material quality can improved storage be substantiated for round bales? What changes in inputs can the operator make to minimize

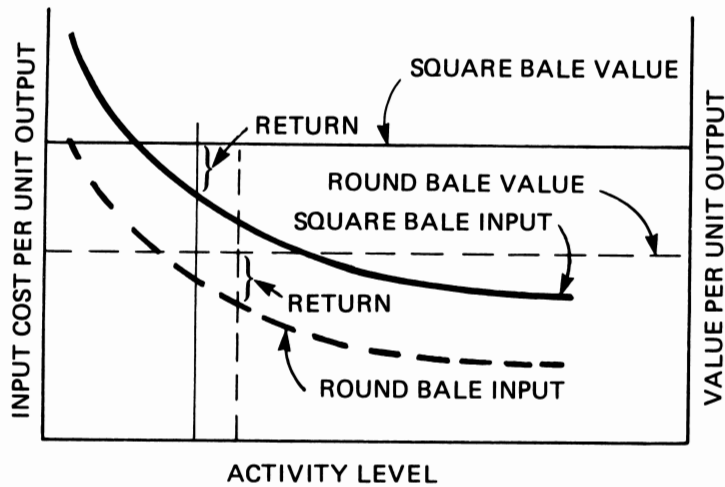


Figure 3. Effect of input substitution on production curve and output value.

the activity level, increase the value per unit output, decrease the input cost per unit output and still maintain an acceptable return?

### METHOD

A set of fixed and variable costs was determined for hay production, harvesting and storage for five different harvesting/storage systems. The value of spoiled hay was introduced to modify the input costs to reflect the input cost per usable tonne of hay. Five typical hay production scales were used to determine the effect of variable costs on total input costs.

The calculated input costs were graphically presented and compared to a current hay value per tonne to determine the relative worth of the different systems at different production scales.

The sources for the costs are noted below and may be considered applicable for hay production, harvesting and storage in a "humid" region, like Ontario.

It is acknowledged that for the purposes of this report some fixed costs were arbitrarily set and the variable costs are based on new equipment and costs of borrowing money known to the author. Farm operators may choose different types of new or even used equipment and may have different dollar costs and costs of operation. These differences will change the optimum decision points for each individual operator.

Fisher (1981), summarizes the hay production costs per tonne for 69 farms surveyed in 1979 at \$56.11 compared to a harvested value of \$57.22. These costs are broken down in Table II.

Fisher (1982), presents a custom swathing rate for hay of \$22.81/ha which would be \$3.53/tonne at 6.47 tonnes/ha. With the cost of hay cutting added to the preharvest and land costs, hay pro-

duction up to and including cutting would be \$32.35/tonne (see Table II). This value was used as a fixed cost per tonne to which the harvesting, transport and storage costs were added for all harvest volumes in this report.

Five systems of hay harvesting were evaluated. Machinery capital costs were sourced from current (1982) agricultural machinery sales manuals. Machinery operating costs were developed using agricultural machinery management data (American Society of Agricultural Engineers 1982). Costs of labor and storage facilities were sourced from local representatives (personal communication with CANFARM and Ontario Ministry of Agriculture and Food (OMAF) representatives, respectively). This information was used to develop total hay harvesting input costs. Studies of hay storage losses were used to enter values for "spoiled hay" (Rider et al. 1979; Verma and Nelson 1981; Parsons et al. 1978). These values were used to modify the input costs to reflect the input cost per usable tonne of hay.

The five hay harvesting systems were:

- (1) square baler – wagons – elevator – storage.
- (2) square baler with thrower – wagons – elevator – storage.
- (3) round baler – bale carrier – outside uncovered storage.
- (4) round baler with circumferential plastic wrap – bale carrier – outside storage.
- (5) round baler – bale carrier – inside storage.

Five annual harvest tonnages (100, 300, 500, 1000 and 1500) were used to calculate individual machinery costs per tonne since both fixed and variable costs

TABLE II. HAY PRODUCTION COSTS (\$/tonne) FOR 69 FARMS IN ONTARIO, 1979 (FISHER 1981)

	Total (\$)	Preharvest (\$)
<i>Preharvest costs</i>		
Labor	0.12	
Tractor and machinery	0.23	
Materials	6.68	
Other	0.12	
Total	7.15	7.15
<i>Harvesting costs</i>		
Labor	5.13	
Tractor	5.39	
Machinery	7.19	3.53
Materials	0.86	
Other	0.94	
Total	19.51	3.53
<i>Overhead costs</i>		
Land	21.67	21.67
Storage	7.34	
Other	0.44	
Total	29.45	21.67
<i>Total preharvest land and cutting costs</i>		
Total costs per tonne	56.11	32.35
Value per tonne	57.22	

change with size of harvest.

The costs of machinery operation included depreciation, investment cost, taxes, overhead, housing, repairs, fuels and lubricants. Tractor costs were based upon using a portion of the tractor's annual hours.

Total costs of hay put into storage were developed assuming no spoilage. Storage costs were based upon constructing a pole-supported roof structure, capable of storing round bales, three bales high. The construction cost was set at \$37.67/m<sup>2</sup> which translated to a cost per tonne per year of:

Round bales, \$8.19/tonne  
Square bales, \$6.14/tonne

Table III illustrates the total land, preharvest and harvest costs (i.e., costs into storage) for the five harvest systems and five annual harvest scales.

Hay quality is measured in many ways depending upon its end use. Visual characteristics, protein content, and total digestible dry matter (DDM) are mentioned quite often in literature and communications. Since most round bales are directed towards the cow-calf beef enterprise or the dairy enterprise for dry cow and heifer feeding, because of the energy and dry matter intake requirements, rather than the protein content, a measure of change of in vitro digestible material (IVD) or digestible dry matter change was taken as a basis for comparison (Rohweder et al. 1977).

Values of losses of hay digestible dry matter were selected that represented

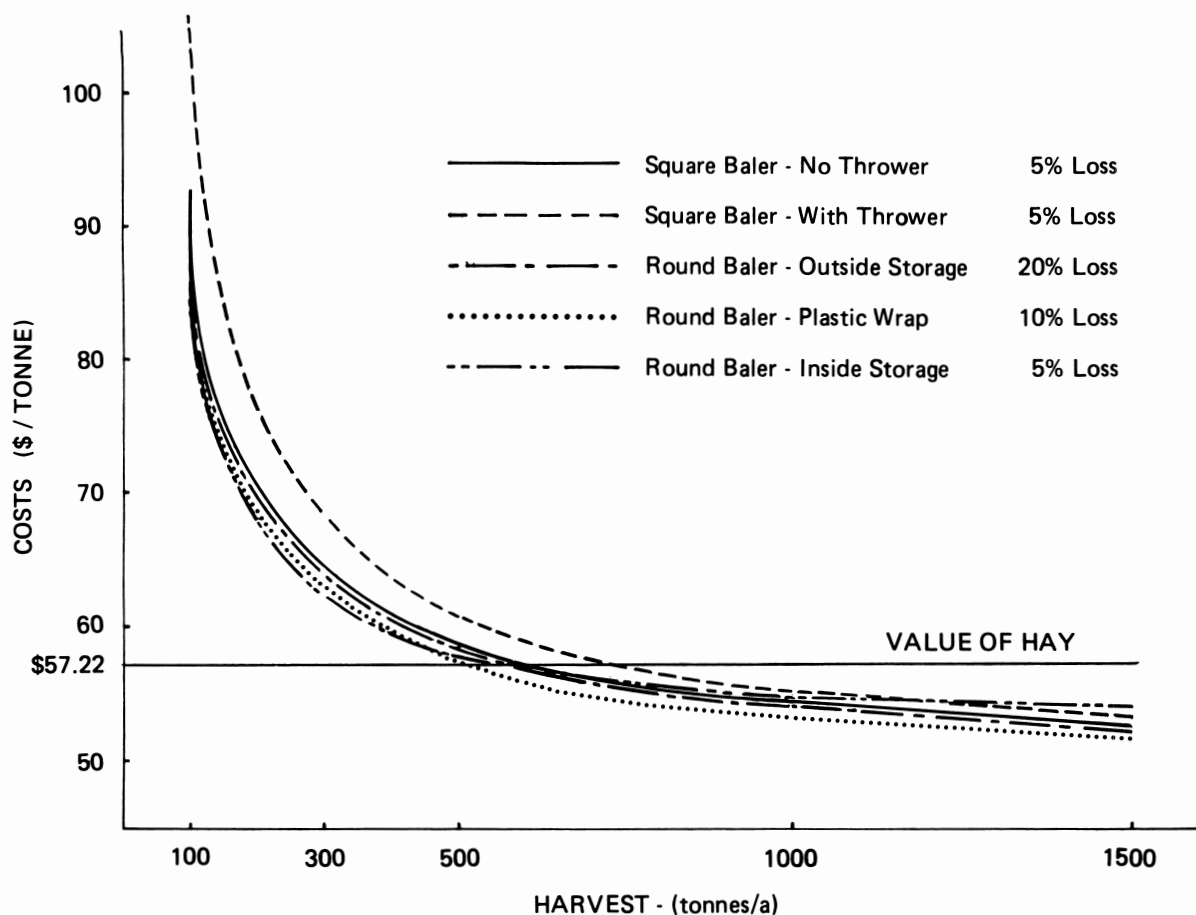


Figure 4. Hay production costs from storage including losses (\$/tonne).

TABLE III. HAY PRODUCTION COSTS INTO STORAGE FOR FIVE SYSTEMS AND FIVE HARVEST SCALES (\$/tonne)

System type	Harvest (tonnes/yr)				
	100	300	500	1000	1500
Square baler, no thrower	88.11	61.17	55.79	51.75	50.40
Square baler, with thrower	100.45	64.85	57.71	52.38	50.60
Round baler, outside storage	72.94	50.94	46.77	43.36	42.29
Round baler, plastic wrap	80.47	56.28	51.67	47.94	46.76
Round baler, inside storage	81.13	59.13	54.96	51.55	50.48

TABLE IV. HAY PRODUCTION COSTS FROM STORAGE INCLUDING LOSSES (\$/tonne)

	DDM loss (%)	Harvest (tonne/yr)				
		100	300	500	1000	1500
Square baler						
No thrower	5	92.75	64.39	58.92	54.47	53.05
With thrower	5	105.74	68.26	60.75	55.14	53.26
Round baler						
Outside storage	10	81.04	57.71	51.97	48.17	46.99
	20	91.18	63.68	58.46	54.20	52.86
Plastic wrap	7.5	86.99	60.84	55.86	51.83	50.55
	10	89.41	62.53	57.41	53.47	51.96
Inside storage	5	85.40	62.24	57.85	54.26	53.14

average occurrences in parts of North America where rainfall is significant (Rider et al. 1979; Moggach and Weedon 1979; Verma and Nelson 1981). Square-baled hay usually loses approximately 5% while stored inside a barn for a year. This same value was assumed for round bales stored inside. Current tests of bales

wrapped circumferentially with plastic stored outside indicate a loss of 7.5–10%. Round bales stored outside with no protection but in a reasonably drained location lose up to 20% of their original dry matter digestibility due to weather, quality as baled and condition of the bale in storage. Two values of digestible dry

matter loss were selected for both outside-stored and plastic-wrapped bales in order to determine the sensitivity of costs to losses.

Table IV illustrates the cost per useable tonne of hay for ranges of change in digestible dry matter (DDM).

Figure 4 illustrates the information in Table IV for the high loss range values and includes a horizontal line at \$57.22 per tonne representing the final value of the hay.

#### OBSERVATIONS

The total hay production cost of \$56.11/tonne, discussed earlier (Table II), was an average of 69 Ontario farms in 1979. The range across Ontario was from \$50.92 to \$61.49. This was affected by farm size, fixed inputs such as land and materials and variable inputs (Fisher 1981). Table III illustrates a considerable variation in the costs of hay put into storage. For this study this variation is due entirely to the variable machinery costs due to different harvesting methods and harvest volumes.

Table IV and Fig. 4 illustrate that, except for very high annual volumes, round bales stored inside have a lower

cost than square bales stored inside. They also illustrate that outside storage of round bales is the least expensive method only if round bale spoilage can be kept below 14%.

In Fig. 4, the curves indicate that hay production does not even become a "breakeven" proposition until an annual harvest volume of almost 500 tonnes. The hay production volumes reported by Fisher (1981) for Ontario averaged near 200 tonnes per year. Certainly, a farmer's expected annual harvest will have a significant effect on his selection of a particular harvest system. The comparison also suggests that harvest machinery is kept longer than the life expectancy that this study used.

Plastic-wrapped bales resulted in a lower cost per tonne of usable hay than any other method except outside-stored, low loss round bales at large annual volumes. This occurred because the cost of the plastic wrap attachment could be spread over a larger production volume, whereas inside storage costs are the same fixed value for all volumes of production.

The relationship between square bales, round bales stored outside and round bales stored inside is the most interesting. In all cases, inside storage of round bales was less expensive than using a square baler with thrower. This might suggest that present storage facilities dictate the farmer's haying method.

The annual cost of storing round bales inside was established at \$8.19/tonne. This is approximately 14% of the market value of hay, suggesting that inside storage should be considered when losses

exceed 14%.

A spoilage of 20% results in the farmer needing more land, labor, equipment and management to harvest his annual hay requirements. If this penalizes his ability to do other work, the penalty cost should be included. This could again improve the worth of inside storage.

### CONCLUSIONS

(1) Round bale harvesting with outside storage and resultant spoilage of 20% was nearly as expensive as square bale harvesting with inside storage.

(2) Round bale harvesting with inside storage was less expensive than square bale harvesting, especially at low annual harvest volume.

(3) For annual harvests under 1000 tonnes, round bale harvesting with inside storage was less expensive than round bale harvesting with outside storage at 20% spoilage.

(4) For annual harvests exceeding 500 tonnes, round bale harvesting with plastic wrap as a storage method becomes more attractive than either inside storage of round bales or square bales.

(5) The annual cost per tonne of inside storage of round bales was established at \$8.19. This is approximately 14% of the market value of hay used in the analysis. This would indicate that if total losses are expected to exceed 14%, protective storage should be investigated.

(6) A penalty cost attributed to the inputs required to harvest hay that will spoil could increase the worth of inside storage.

### REFERENCES

- AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS. 1982. Agricultural Engineering Yearbook. St. Joseph, Mich.
- CURRANCE, H. D. and A. G. MATCHES. 1976. Large bale storage losses. Paper no. 76-1510. Am. Soc. of Agric. Eng., St. Joseph, Mich.
- FISHER, G. A. 1981. Economics of hay production in Ontario. 1979. Economist. Economics Branch, Ont. Min. of Agric. and Food, Toronto, Ont.
- FISHER, G. A. 1982. A survey of custom farmwork rates charged in Ontario. 1981. Economist. Economics Branch, Ont. Min. of Agric. and Food, Toronto, Ont.
- FRIESEN, O. H. 1980. Economics of forage equipment and feeding systems. A paper presented at the Cattlemen's Short Course, Banff, Alberta. 8-12 Dec.
- MOGGACH, G. S. and J. K. WEEDEN. 1979. Large package hay equipment — new concepts in hay making. Ont. Min. of Agric. and Food, Ext. Eng. Agdex 120/745.
- PARSONS, S. D., V. L. LECHTENBERG, D. C. PETRITZ, and W. H. SMITH. 1978. Storage and feeding of big-package hay. Grain and forage harvesting. Am. Soc. Agric. Eng. 78(1): 290-292.
- RIDER, A. R., D. BACHHELDER, and W. McMURPHY. 1979. Effects of long-term outside storage on round bales. Paper no. 79-1538. Am. Soc. Agric. Eng., St. Joseph, Mich.
- ROHWEDER, D. A., R. F. BARNES, and N. JORGENSEN. 1977. Marketing hay on the basis of analysis. A paper presented at the Tenth Res. Ind. Conf. of the Am. Forage and Grassland Council.
- VERMA, L. R. and B. D. NELSON. 1981. Effects of storage method on quality changes in round bales. Paper no. 81-1515. Am. Soc. of Agric. Eng., St. Joseph, Mich.