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Biomass Energy Production Alfalfa Supply System

Hay Storage Losses

MINNESOTA AGRIPOWER PROJECT
TASK II RESEARCH REPORT

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Alfalfa Hay Storage Losses Study as Influenced by Bale Type and Storage Method

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This experiment was conducted in cooperation with the Minnesota Alfalfa Producers (MnVAP) cooperative. Alfalfa for use as both a biomass energy source and as a protein supplement has been proposed by MnVAP. Therefore, factors that affect alfalfa hay, leaf and stem ratio, or leaf and stem quality may effect the value of that alfalfa as a source for electrical energy and as a protein supplement.

Alfalfa actively grows in Minnesota for about 5 months; however, alfalfa will be needed on a year-around basis for the MnVAP plant. In addition, research has shown that alfalfa deteriorates over time in storage, and that storage method and bale type affect the amount of deterioration. Therefore, evaluation different storage methods and bale types on dry matter and quality losses of alfalfa leaf and stem components is important information for both the alfalfa grower and the MnVAP cooperative.

Materials and Methods:

The research project consisted of 2 bale types: 1) 3x4x8 foot rectangular bales, and 2) 5x6 foot round bales and 4 storage methods: 1) under a pole barn, 2) outside on the ground, 3) outside on gravel, and 4) outside on gravel and covered. A stack of 3x4x8 bales consisted of 11 bales, three rows of three bales with two bales placed on top over the seams of the first three rows of bales. A stack of round bales consisted of a pyramid of bales with 3 bales in the bottom row, 2 in the middle row, and a single top bale.

The experimental design was a split-split plot with two replications. Storage method was the main plot factor, bale type was the subplot factor, and sample location in the bale was the sub-subplot factor.

The research storage site was located at the West Central Experiment Station, near Morris, MN. The alfalfa used in this experiment was third harvest hay cut in early September 1996 and was grown, harvested, and shipped by Mr. Dru Tossel to the West Central Experiment Station where bales were randomly assigned to storage treatments. Measurements taken included: initial and final bale weights, dry matter, leaf and stem components and forage quality estimates.

In June 1997, samples for each bale type and storage treatment were taken from hay surfaces exposed to the ground (0 - 6 in.), exposed to the environment not in contact with the ground (0 - 4 in.), from watershed areas where bales contact each other (0 - 6 in.), from the bottom of the bale but beyond the area of visible spoilage (6 - 14 in.), and taken from the internal area of bales (4 - 14 in.). Approximately 20 core samples from random locations on bales within each stack and each sample type were taken and composited. Samples were split with one half left intact for whole plant evaluation and the other half separated into leaf and stem components. Leaf and stem percentages, crude protein (CP), neutral detergent fiber (NDF) and relative feed value (RFV) of the whole plant, leaf and stem components will be estimated using near infrared reflectance spectroscopy (NIRS) equations developed from wet chemistry analysis.

Literature Review

Alfalfa dry matter losses can be affected by storage method. In Oklahoma, dry matter losses ranged from less than 2.0% for hay stored on pallets under covers to 13.1% for hay stored on the ground without covers (Huhnke, 1988). Dry matter losses in excess of 40.0% have been reported for unprotected bales stored on the ground in Louisiana (Verma and Nelson, 1983). Rider et al. (1979) reported that bales stored in a barn had lower dry matter and digestible dry matter losses than bales stored in contact with the ground. They also reported moisture accumulation in the bottom of bales stored on the ground. Average moisture content of the unprotected bales stored on the ground increased over 70% (from 12.0 to 20.5%, wet basis). In southern Wisconsin, dry matter losses ranged from 4.6% for barn storage to 10.9% for uncovered bales stored on the ground (Collins et al., 1987). They determined changes in forage quality parameters for both the total bale and the weathered layer. The weathered portion of bales ranged from nil for inside storage to 15.5% for bales stored unprotected, outside. Bales stored inside lost less in vitro digestible dry matter compared to those stored outside. It is not known how losses in dry matter, or changes in moisture or nutritive value affect leaf and stem components of alfalfa hay and ultimately alfalfa hay as a biofuel and protein supplement.

Results and Discussion

Dry matter losses:

There were few differences detected among bale types for dry matter losses. In addition, interactions among bale type and storage method were not detected. This indicates that dry matter losses were similar for the round bales and square bales regardless of the storage method. However, differences in dry matter losses and visible spoilage at the bottom of the bales were detected among storage methods.

Table 1. Percent dry matter losses by storage treatment for alfalfa hay stored from September 1996 to June 1997.

Storage method	Percent DM losses
Barn	2.3a*
Pasture	11.2c
Gravel - Uncovered	10.9c
Gravel - Covered	4.8b

* Values followed by different letters are significantly different at an LSD of 0.05

Table 2. Percent dry matter losses by bale type for alfalfa hay stored from September 1996 to June 1997.

Bale type	Percent DM losses
Square	7.3a*
Round	7.3a

* Values followed by different letters are significantly different at an LSD of 0.05

Table 3. Visible spoilage on the bottom of bales as a percentage of the total bale for different storage methods and bale types of alfalfa hay stored from September 1996 to June 1997.

Storage method	Square bales	Round bales
	----------- % of bale volume --------	
Barn	<1	<1
Pasture	22	23
Gravel - uncovered	8	7
Gravel covered	8	<1

Table 4. Post storage dry matters by storage method, bale location, and bale type for alfalfa hay stored from September 1996 to June 1997.*

Storage method	Bale location	Square bales	Round bales
		----------- % dry matter ------------	
Barn	All bales	82.4a	81.8a
Pasture	bales on ground	68.8d	68.1d
	other bales	77.6bc	81.7a
Gravel - uncovered	Bales on ground	75.2c	77.3bc
	other bales	76.7bc	79.1ab
Gravel covered	All bales	81.4a	82.1a

* Values within and between columns and rows followed by different letters are significantly different at an LSD of 0.05

<u>Dry matter loss observations:</u>

- Dry matter losses were over 10% for hay that was not covered during storage (Table 1)

- Bales in contact with the soil on pastures had over 20% of the total bale volume visually spoiled (Table 3)

- Very few differences were found in storage losses between round and square bales (Tables 2, 3,and 4).

- Round bales stored in contact with the ground compressed. This may cause difficulty with shipping

Forage quality:

No interactions between bale type and storage method were detected for forage quality parameters, this indicates that forage quality losses as a result of storage were similar between large round and large square bales. Bale type by sample type and storage method by sample type interactions were detected. Many of these were the result of poorer quality of alfalfa stored on the pasture.

Table 5. Bale type by sample type interactions for forage quality parameters of alfalfa hay, leaf and stem samples from alfalfa hay stored from September 1996 to June 1997 near Morris, MN.

Bale. Type	Sample Location	% Leaf	CP*	NDF	RFV	Leaf CP	Leaf NDF	Leaf RFV	Stem CP	Stem NDF	Ste RF
			%								
R	Ground	35.0	21.3	58.8	89	27.9	43.6	150	15.5	66.8	67
	External	37.0	22.7	49.5	112	29.1	36.6	180	15.1	62.7	77
	Watershed	33.5	22.7	53.9	98	29.5	37.3	169	16.8	63.1	76
	Internal	34.9	23.8	47.6	118	28.6	33.5	195	16.5	58.7	85
	Bot. Internal	34.8	22.1	51.3	105	29.4	33.1	198	16.4	58.6	84
S	Ground	35.7	20.4	60.4	85	25.2	48.9	126	14.8	72.2	60
	External	35.1	23.6	44.8	128	29.4	32.5	203	16.1	58.4	85
	Watershed	33.7	20.8	59.1	86	28.4	38.8	163	16.1	59.5	82
	Internal	34.9	22.5	50.4	111	27.2	36.6	184	15.9	60.6	81
	Bot. Internal	36.5	22.7	50.3	111	28.5	36.6	183	16.3	62.5	77
	LSD (0.05)	NS	1.1	4.3	11.9	NS	2.8	17.0	NS	3.6	6.6

*R = round bales, S = square bales, CP = crude protein, NDF = neutral detergent fiber, RFV = relative feed value

Table 6. Leaf crude protein for large round and square bales of alfalfa hay stored from September 1996 to June 1997 near Morris, MN.

Bale type	Leaf crude protein
Square	27.9a*
Round	28.8a

* Values followed by different letters are significantly different at an LSD of 0.05

Table 7. Storage treatment by sample type interactions for forage quality parameters of alfalfa hay, leaf and stem samples from alfalfa hay stored from September 1996 to June 1997 near Morris, MN.

Stor. Type	Sample Location	% Leaf	CP*	NDF	RFV	Leaf CP	Leaf NDF	Leaf RFV	Stem CP	Stem NDF	Ste RF
			%								
Barn	Ground	33.4	23.1	51.4	106	29.9	36.7	179	16.0	58.3	75
	Internal**	33.5	23.6	30.2	133	30.2	29.1	232	17.0	54.8	94
Past.	Ground	31.2	17.4	74.9	55	22.0	62.4	86	15.0	80.7	48
	External	32.9	22.6	51.3	107	28.4	36.9	175	14.0	64.7	72
	Watershed	33.2	22.2	55.7	92	28.1	40.8	149	15.6	63.7	74
	Internal	41.4	23.3	48.7	114	29.0	34.4	189	14.8	61.1	79
	Bot. Internal	37.3	21.8	60.7	81	26.6	48.3	116	16.0	72.7	58
G-un	Ground	39.6	21.8	55.4	94	27.0	45.7	128	14.5	71.3	60
	External	35.1	23.4	48.8	115	29.4	38.5	164	15.4	63.7	74
	Watershed	35.1	21.6	57.6	90	29.6	35.9	177	16.9	60.9	80
	Internal	31.3	22.9	53.2	102	28.2	39.8	162	16.5	63.4	76
	Bot. Internal	40.7	23.4	45.1	127	29.1	32.7	200	15.3	60.6	79
G-c.	Ground	36.1	22.5	52.1	103	29.8	34.1	192	15.7	60.8	80
	External	31.4	23.1	44.9	127	29.1	34.7	188	16.2	59.5	82
	Watershed	31.1	22.2	53.2	101	30.0	36.1	178	17.8	59.3	84
	Internal	32.0	23.6	44.4	130	27.6	30.2	221	17.5	54.0	96
	Bot. Internal	32.6	22.8	47.2	119	29.6	30.4	220	17.2	55.8	91
	LSD (0.05)	NS	1.6	6.2	16.8	2.6	3.9	24.0	NS	5.1	9.3

*Stor. = storage; R = round bales; S = square bales; CP = crude protein; NDF = neutral detergent fiber; RFV = relative feed value; Past. = hay stored on a pasture; G-un = hay stored on gravel; uncovered; G-c = hay stored on gravel and covered with a tarp.

** Not all samples were taken from hay stored in the barn since all it was not exposed to weathering or moisture. Thus only samples from the bottom and from the internal part of the bale were sampled.

Table 8. Stem crude protein by storage treatment for alfalfa hay stored from September 1996 to June 1997 near Morris, MN.

Storage method	Stem crude protein
Barn	16.7a*
Pasture	15.0b
Gravel - Uncovered	15.8b
Gravel - Covered	16.8a

* Values followed by different letters are significantly different at an LSD of 0.05

Table 9. Stem crude protein by sample location for alfalfa hay stored from September 1996 to June 1997 near Morris, MN.

Storage method	Stem crude protein
Ground	15.2b*
External	15.6a
Watershed	16.5a
Internal	16.3a
Bottom - Internal	16.3a

* Values followed by different letters are significantly different at an LSD of 0.05

Forage quality observations

- Weathering and a concomitant reduction in forage quality occurred in both the leaf and stem components but was greater in the leaf component (Tables 5 and 7).

- Averaged across internal bale samples, leaf CP was 28.8% (Table 7). Thus, assuming perfect leaf and stem separation and optimal storage conditions, 28.8% CP would be the theoretical optimum for CP of an alfalfa pellet from this hay.

- Leaf and whole plant CP was affected by storage location and by sample location within the bale (Table 7). Leaf CP ranged from 22% from leaves in the bottom 6 in. of the bale stored on pasture to 30.2% for leaves inside of a bale stored in a barn. Except for this example, most differences in leaf CP were relatively small. However, protein digestibility was not measured. It is possible that although protein concentration often did not change with weathering, the nutritional availability of that protein may have.

- Non-significant bale type by sample location interactions for leaf and stem CP (Table 5) indicate that leaf and stem CP responds similarly across sampling locations regardless of whether it is in round or square bales.

- The effect of storage on leaf RFV was much greater than the effect of storage on leaf CP. Leaf RFV ranged from 86 from leaves in the bottom 6 in. of the bale stored on pasture to 232 for leaves inside of a bale stored in a barn.

- Initial whole plant hay RFV (124) was similar to alfalfa from in the internal area of bales stored in the barn (133) and on gravel and covered (130). This indicates that alfalfa quality can be maintained with good hay storage management.

- Percent leaf was not affected by bale type, storage method, or sample location (Tables 5 and 7). Thus, changes in leaf and hay quality would be the result of changes in chemical composition of leaves and stems and not in leaf to stem ratio.

- Forage quality of stems, (stems made up almost 65% of these samples) were also affected by storage management and sample type. A lower stem RFV implies a lower energy content of the stem material.

- RFV as an indirect measurement of energy content was lower for alfalfa hay, leaves, and stems in contact with the ground than for alfalfa on other portions of the bale (Table 5). Since when alfalfa was stored in the pasture the portion in contact with the ground was greater than 20% of the bale volume this could result is substantial losses in alfalfa energy content.

- Differences in leaf quality of alfalfa stored in contact with the ground (from 0 to 6 in.) between hay stored on pasture and on gravel uncovered indicate the benefits of storing hay off the ground (Table 7). Further increases in forage quality between hay stored on gravel and uncovered and hay stored on gravel covered indicate further benefits to covering hay in preserving hay quality.

- When bales were sampled internally from the bottom of the bale (6 - 14 in. up from the bottom of the bale) only bales stored in pastures had significantly reduced hay and leaf quality (Table 7). This was probably the result of water wicking up into those bales from the soil. This indicates that when stored in contact with the ground, a decline in forage quality can occur even when hay looks 'ok'. In addition, internal samples (taken from 4 to 14 in. into the bale) tended to be better for hay stored in the barn or under tarps than for hay stored on pasture or on gravel and uncovered (Table 7). This also indicates that leaf and hay quality degradation can go deeper into the bale than is visible.

<u>Economic Considerations</u>:

- If alfalfa hay dry matter losses are 10% loss on 200 tons of hay and that hay is valued at $70/ton, monetary losses from reductions in dry matter losses would be $1400.

Perhaps a more realistic way of looking at the whole picture would be to use the prices MnVAP paid for the hay at the end of the study.

- MnVAP offered $45/ton for hay stored in the pasture or on gravel uncovered and $75/to for hay stored in the barn or on gravel and uncovered so, for example:

For hay stored uncovered 200 tons at $45/ton =	**$9000**
For hay stored covered 200 tons at $75/ton =	**<u>$15000</u>**

Additional value of good hay storage for 200 tons of hay = **$6000**

- Bales stored under cover (in the barn and on gravel and covered) was worth $30 more/ton to MnVAP than hay stored outside without cover. Under those circumstances it won't take many years or acres to pay for a pole barn or a hay cover system.

The quality of alfalfa stored on gravel and covered was generally similar to that stored in the barn. This indicates that alfalfa storage does not need to be elaborate to have a large impact on maintaining the quality of alfalfa.

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